JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

Vol. 34 JANUARY 1942 No. 1

Contents

Soliloquy—A Bit of Hydraulics, Psychology and Common Sense. By D. R. Taylor 1
Water Supplies for the Army. By W. A. Hardenbergh 11
Cross-Connection Control. Committee Report 17
Legal Responsibility of Minnesota Municipalities for Polluted Water. By O. C. Peterson 37
Some Legal Aspects of Sewage Treatment. By Grover Jones 53
State Engineering Aid to New Mexico Municipalities. By W. Carlos Powell 56
Maintenance and Protection of Elevated Water Tanks. By H. F. Stearns 59
Maintenance of Elevated Tanks and Standpipes. By Charles J. Leary 63
Progress Report. American Research Committee on Grounding. 69
Corrosion Study of Bolting Materials and Coatings. By Otto A. Halvorson 76
Study of Solubility of Two Lead Salts in Dilute Solutions With Special Reference to the Lead Hazard in Drinking Water. By C. C. Ruchhoft and John F. Kachmar 85
Accelerated Tests for Determination of Attrition Loss of Carbonaceous Zeolites. By S. J. Broderick and E. S. Hertzog 94
Rehabilitation of the Philadelphia Water Works. By Seth M. Van Loan 107
Discussion by Nathan B. Jacobs 114
Meter Maintenance Practice. By A. P. Kuranz 117
Comprehensive Survey of Large Meters in Nashville. By R. E. Lawrence Jr. and Allan R. Sharp 121
Abstracts 130
Guide for Preparation of Journal Manuscripts With a List of Standard Abbreviations 161
Priorities Information—Amendments to Preference Rating Orders 168
Coming Meetings vi
Changes in Membership viii
News of the Field 1

***All correspondence relating to the publication of papers* should be addressed to**

Harry E. Jordan, Secretary
22 East 40th St., New York

$7.00 of Members dues are applied as subscription to the Journal
Additional single copies to members—50 cents
Single copies to non-members—75 cents

Mobile Protection

FOR WATER SUPPLIES

HERE'S THE NEWEST CONTRIBUTION of W&T engineering to public health defense . . . a trailer-type mobile chlorinating unit, designed to provide positive protection of water supplies under emergency conditions, or to meet any need for closely controlled chlorination "on location" without delay.

Using the dependable W&T vacuum principle, the unit provides for solution feed of chlorine over a wide range of application rates up to 100 lb. of chlorine per day. Self-powered by a gasoline motor, it will draw injector water from an open source or pipe line, and apply the chlorine in the main against pressures as high as 100 lb. per sq. in. Two 150 lb. chlorine cylinders are cradled in the trailer, connected to assure continuity of supply. Hoses, cocks, tools and other accessories for making emergency main connections are provided.

Data and experience gained by W&T technical experts in England during the past year, backed by W&T's continuous experience with emergency chlorination equipment extending from before the last World War, are reflected in the design and construction of the unit.

Both trailer frame and chlorinator are designed to stand up under the strenuous conditions of transport and service which exist during emergencies when faithful performance is most essential. Construction is exceptionally rugged to provide ample strength for rigorous duty.

SA 12CA

WRITE TODAY FOR COMPLETE STORY

W&T *"Technical Publication 228"* describes the new Emergency Chlorination Trailer in detail.

New booklet *"A Sound Defense for Your Water Supply"* gives 7 point plan for total protection, including data on emergency chlorination. Ask for W&T Technical Publication 225.

The assistance of W&T Representatives who are specializing in emergency protection plans is also available without obligation. Just call your local W&T Representative or write direct to:

"The Only Safe Water is a Sterilized Water"

WALLACE & TIERNAN CO., Inc.

MANUFACTURERS OF CHLORINE AND AMMONIA CONTROL APPARATUS • NEWARK, N. J. • REPRESENTED IN PRINCIPAL CITIES

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

COPYRIGHT, 1942, BY THE AMERICAN WATER WORKS ASSOCIATION

Reproduction of the contents, either as a whole or in part, is forbidden, unless specific permission has been obtained from the Editor of this JOURNAL. The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

Vol. 34 January 1942 No. 1

Soliloquy

A Bit of Hydraulics, Psychology and Common Sense

By D. R. Taylor

IF WE were engaged to make a survey of the average water plant to make recommendations for efficient operation of that plant, we would undertake the job without any feeling of precociousness, because we are confident that the scientist who said that we did not know one-tenth of what our successors would know in another hundred years was right. We crawled up through our shirts for two thousand years before someone had sense enough to split them up the middle and sew buttons on them.

The suggestions that we would make would be prompted by a sincere effort to follow the precedent already established in the water works field—to pass along some observations and experiences that might be of some benefit in elevating the water works engineer to his rightful position in the order of things, and an effort to assist our fellow superintendents toward more efficient operation.

The efficient operation of any water department or any other kind of business for that matter, like a sound democracy, depends upon only two things—character and intelligence.

Based upon the correctness of this assumption, we would start with the organization. First, we would suggest an itinerary. If you were planning a tour of any extent, the most natural thing for you to do first would be to procure such maps and guides as you thought were necessary to enable you to select a route that would take you where you wanted to do and enable you to arrive there when you thought you should.

A paper presented on October 17, 1941, at the New Jersey Section Meeting, Atlantic City, N. J., by D. R. Taylor, Supt., Water Dept., Roanoke, Va.

Organization Should Be Studied

An organization chart would be our first suggestion. Take a look at your entire organization on paper; then break it down into departments and list the duties of each individual, and we feel sure that you will immediately notice some inequalities, some congestion at some places, and some scant spots at others. This is a mighty good way of locating your "bottlenecks." You may realize the need of some reorganization. Such a need is quite prevalent in many water plants.

This is a matter that one often realizes and observes with trepidation and yet postpones with growing concern. It is like shaving—the longer one puts it off, the harder it is to do. Take our word for it—it is a difficult thing to do at any time, but surely this is no time to vacillate or procrastinate; it is easier to do it now than it will be later on.

Your personnel should be carefully studied and misfits shifted to positions more suitable to their equipment. Key positions should be adequately filled even if it is necessary to resort to some importation.

There has never been a time when leadership was at such a premium as it is today. Arthur W. Newcomb has said: "The *character* and qualifications of the leader are reflected in the men he selects, develops, and gathers around him. Show me the leader, and I will know his men. Show me the men, and I will know their leader." Those are words of wisdom that we are sure no one will attempt to refute.

We would place *character* as first in importance. A man of high character is usually one who possesses some degree of personality, and if the choice lies between personality and intelligence, we favor personality. An employee can be taught to be capable, but it is extremely difficult, even in a lifetime, to teach him sufficient personality if he came into this world without it. One modern saying is, "It's not what you know that gets you ahead, it's whom you know." There is another one that goes like this: "You had better be good to the people you meet on the way up, because they are the same people that you will meet coming down." Those sayings were originated by those who lacked that intangible something called personality; who had become chagrined watching others pass them on the way up.

Next to character comes intelligence. The difference between a master leader and a master crook is that the leader has character and intelligence; the crook has only intelligence.

As the next requisite for our key men, we would stress general deportment. We would pick men with clear heads and level heads; men who were not inclined to become panicky in an emergency; men who were not inclined to brood or worry over actual or potential troubles; men who were capable of thinking things through. A clear mind is the usual result of a healthy body, and a healthy body and a clear mind usually denote efficiency.

We spent a few days on a farm one summer, far away from the beaten paths, where there was nothing to do but eat, sleep, and rest. One day we drove over to visit a neighboring farmer and "chew the fat" with him about nothing. As we were leaving, we inquired casually, as a parting remark, if he thought it would rain. "Well," he said, "I guess it will; it always has." Now there is a fellow who will live forever. He has the greatest philosophy of life of all; he doesn't worry. We know that that farmer works from dawn till dark; that he is diligent, keen, alert, frugal, and successful; a pillar in his church, prominent in the affairs of his county, and respected by his friends and associates—that's the type for the heads of your departments.

Organization is the major item. With the organization perfected, a group meeting of all employees should be held. At this meeting, stress should be placed upon intelligence—intelligence as exemplified by assiduous attention to details, honest effort, earnestness, judgment, co-operation, teamwork, loyalty, a sense of responsibility, and the proper perspective and co-ordination on the one side and the proper attitude in all dealings with customers on the other side.

We would stress the importance of building and conserving public relations and go very thoroughly into the minute details necessary for accomplishment along these lines, enumerating the importance of judgment and an even disposition, a thick skin and the ability to swallow often and to stick to one's story. We would demonstrate to this group, if necessary, the proper and improper approach and proce-

Public Relations Should Be Courted

dure to be used in waiting on customers, selecting several typical complaints for examples. A customer will be considerate if the employee will just let him tell his story without being interrupted. He probably has been rehearsing the story for a week and will feel much better if you let him tell it.

Occasionally one runs into a customer who insists on being just plain mean, like the golfer who was off his game and lost all his bets and remarked that when he arrived home, if dinner wasn't ready, he was going to raise h——; and if dinner was ready, he wasn't going to eat a d—— bite. Dealings with such a customer require a lot of swallowing and a lot of patience, but he can be worn down with the necessary perseverance.

It has been said that "the most precious thing anyone, man or store, or water department, if you please, can have is the friendship and the good will of others. It is something as fragile as an orchid and as beautiful; as precious as a gold nugget and as hard to find; as powerful as a great turbine and as hard to build; as wonderful as youth and as hard to keep."

Stressing public relations to your employees is like making love to an old maid—it can't be overdone. Good public relations can offset many deficiencies, but the best service in the world can fail in accomplishment if it is accompanied by poor public relations.

Economies Within the Organization

Now that the organization has been properly instructed as a group, let us look into the work of the various departments. We would start first with the auditing department and have it set up a system of accounts that would furnish complete information in the simplest manner—a system similar to the uniform system of Accounts for Water Utilities and the List of Retirement Units for Water Utility Property as promulgated by the National Association of Railroad and Utilities Commissioners. How can you determine whether you are progressing or retrograding without daily, monthly, and annual comparisons?

We would have a monthly statement prepared, that, in addition to assets and liabilities and the usual accounting items, would show a monthly comparison of capital additions, maintenance and operating costs, itemized for each division, and the corresponding figures for the same month one year prior. A comparison of these same items should also be shown between the total to date of the current year with that of the previous year; and there should be included a statistical sheet showing a similar comparison of physical quantities such as mains, valves, fire hydrants, active and inactive services, gain or loss in customers, gallons input, gallons sold and used for operations, unaccounted-for water, gallons of water produced per pound of coal, gallon of oil, per kilowatt hour, etc., and corresponding comparative figures for filter plant operations. There should be correlated with these

records, on proper printed forms, by all outside and inside departments, all details of operation, which should terminate in the accounting department and proper record files. How do you know if you are installing mains or services at less cost this year than last? How do you know whether you are producing water for more or for less this year than you did last year? How do you know anything without an adequate accounting system?

At the beginning of this preparation period, the duties of the engineering department would be manifold, probably requiring the addition of several temporary employees. We would start this department gathering information for the design of an efficient meter maintenance program, which, at the outset, would require the equipment of a good meter repair and testing shop, as well as portable testing equipment for use in the maintenance of large meters in the field. Also, proper test specifications should be prepared, stipulating allowable tolerances for all test rates for all types of meters.

This is a most important item, for you know that "as your meters go, so goes your revenue." This would be an opportune time to increase your revenue to help offset the extra expense of putting your house in order. We know of one water department that increased its annual revenue about $4,000 from large meters alone by the institution of a carefully designed comprehensive meter maintenance program, with an expenditure of not more than $1,000; and it is believed that an equal increase was realized from small meters with a corresponding relatively small increase in maintenance and operating expense. We know of cities that we honestly believe could increase their annual revenue from $5,000 to $10,000 with an increase in operating expenses of not over $2,000.

With the aid of test meters and recorders, sufficient information should be obtained to indicate rather conclusively, with respect to small meters, the average percentage of under-registration and the percentage used at various rates. With this information, an average economical service life of small meters should be selected. By service life is meant the length of time a meter should be allowed to stay in service before it is removed for test. The actual determination of this service life can be done only by a cut

These Dollars Can Be Caught

His Ills Should Be Administered To

and try method, but, by a comparison of the cost of repairs with the revenue lost during the period in question, a proper economic limit of meter maintenance can be determined definitely after a few test periods of meters of various service lives.

Coincidental with the preparations already mentioned, we would engage a reputable firm to make a waste survey and a distribution study. At the end of the survey, and based on its results, we would determine the size and age of the plant and the condition of its facilities and decide whether we would purchase the necessary equipment and make an anual check ourselves, or whether it would be more economical to have the work done by contract, periodically, as determined by the percentage of unaccounted-for water shown by properly kept records.

We would be particularly interested in velocities and friction coefficients of principal mains and would spot-check these mains annually, if necessary, to observe any changes. These data are useful in many ways. They would indicate the annual rate of decrease of carrying capacity of these mains, cognizance of which should be taken in the design of future extensions. These figures would indicate any necessity for corrosion control. If corrosion control were already in use, they would determine its success and the advisability of changes of dosages, or even changes in methods of treatment.

During this survey, all pumps should be tested and a thorough investigation should be made of the metering equipment at each source of supply. It would be recommended that each of these meters be overhauled and tested and that any found unreliable be replaced with modern measuring instruments. It is absolutely impossible to determine quantity of unaccounted-for water without accurate meters, and a plant operating without an accurate record of unaccounted-for water is similar to a grocery store operating without a cash register or a bank deposit book. May we interject another thought here? In many instances, the only datum for determining an accurate figure for unaccounted-for water is a waste survey. How do you know that your figure of 25 per cent is good? You may have a 500,000 gpd. leak and your figure should perhaps be 15 instead of 25 per

cent. This survey is another opportunity to secure a net increase in revenue to help pay for the transformation.

In this connection, a program should be adopted for testing all pumps at least annually. A pump bought last year with an efficiency of 75 per cent may, due to a change of conditions, have an efficiency of only 40 per cent this year. You may be losing $10 per day, when a new impeller, which would cost only $20, would be paid for in two days. On the other hand, you may have a pump which runs intermittently, we will say, a total of 6 hr. per day, pumping to an elevated tank, against a high friction head. A test of this pump might prove that you could well afford to replace it with a pump of a lower capacity, with a correspondingly lower friction head, and save a large amount on power costs, even though it be necessary to run it a greater number of hours per day.

We know of a case where a pump with a capacity of 700 gpm. was producing a friction head of 90 ft. This pump was supplying an elevated tank and was run only 6 hr. per day. A test of the pump indicated that a 250-gpm. pump, which would run almost three times as long each day, would, due to a great reduction in friction head (which can be determined easily with one of the conversions of the Williams-Hazen formula), save about $75 per month on power costs. The change was made and the anticipated savings realized. The old pump was left intact for standby use.

Planning for the Future

After this survey was completed, we would, with the aid of its findings and the latest recommendations of the National Board of Fire Underwriters, prepare a ten- or fifteen-year construction program. This being an important major item and one in which large amounts of money can be easily and unwisely spent, we would not hesitate to secure the services of the best consulting engineers, with experience in this particular phase, to assist in the design of the program. Such a program is vastly important, because, by adherence to it, much duplication of effort and expense can be avoided. For instance, if the program called for a 20-inch header across one end of your city in five years; and, in the meantime, ordinary growth required an 8-inch extension for, we will say, 1,000 ft. along a portion of the route of the proposed 20-inch main, it would, of course, be wise to lay the 1,000 ft. with 20-inch pipe now.

Along with its other work, we would recommend that the engineering department begin the compilation of a complete physical inventory of the entire plant with proper maps and records, showing on these maps and records the date of each installation so far as all previous records would show and old employees could remember. With these figures, a perpetual inventory of all facilities could be started and kept up to date monthly.

Examine Them Annually

These records would become increasingly valuable, not only for determining the real capital value of the plant, but also in the determination of proper figures for the service life of facilities and equipment and depreciation and obsolescence.

We would suggest that an annual valve and fire hydrant inspection program be adopted. To some initiates in the water works field, this is something with intangible aspects; but those with experience know that the value obtained is well worth the price.

Proper specifications and blueprints of standard construction should be prepared and followed. Standardization of two or not over three different makes of valves, fire hydrants, meters, etc., will also serve to keep your stock of materials and supplies low, and eliminate lost time, confusion, and extra and unnecessary expense.

Another important item is that of miscellaneous equipment such as flow recorders, pitot tubes, manometers, pipe locaters, leak locaters, gauges, etc. Good equipment stimulates pride in your employees and makes for efficient operation. Do not overlook the value of such a good investment.

Our final recommendation is the most important one. So far the major part of our theme has been character—character of organization, of personnel, facilities, equipment, engineering, operation, procedure, and policies. For effective results, this character must be accompanied by intelligence. What about your Superintendent, Chief Engineer, or whatever you may call him? The fountain head of the intelligence of any organization is in the man who directs its affairs. It is from this source that wisdom, judgment, enthusiasm and incentive emanate, diffuse and permeate the entire organization. The influence of proper leadership is catalytic in its action. It can be used over and over without wearing out. Remember, "show me the men, and I will know their leader."

For those few plants that, like Topsy, have "just growed" and are not already blessed with a capable, technically trained Superintendent or Chief Engineer, we would strongly urge that the investment be made.

If your plant falls in the category of having a capable, commendable and loyal head, of many years service, whose burdens have been increased gradually from year to year to a disproportionate, but perhaps unrealized,

immensity, you may be disinclined to mention to him the advisability of giving him some well-deserved assistance by the employment of another engineer, for fear that he might misunderstand your intentions or that his pride will be injured or his feelings hurt. Cease to worry. You are laboring under a misapprehension. He will welcome and appreciate such assistance if you employ the right sort of man. If the new man has "what it takes," he will win the confidence and respect of the entire organization and make you proud of this new addition to your organization. This is not fantastic; we have seen it done.

There are still a few water works executives, who will willingly spend many thousands of dollars per year for main extension for a return of only 6 per cent on the investment, who cannot see the wisdom of paying the necessary amount to secure a capable engineer who could probably effect a return of 50 to 100 per cent on the investment.

The program that we have suggested is not idealistic—such a program is being followed in many successful plants—nor is it difficult. It is just a matter of making a plan and following it, and the time required to get into full production can be controlled to meet your own particular conditions and to allow new practices to help pay their way.

Obviously we have touched on only the major points. It is well understood, we are sure, that there are innumerable details requiring proper attention from someone, all of which can be delegated to various individuals in the different departments. The master plan is the main thing; the details will prove simple.

In this connection, we are reminded of the young graduate engineer, engaged by a lumber company, who considered how he would cut a tapering log in two pieces so that each piece would contain the same number of board feet of lumber. With the aid of higher mathematics and several hours of effort, he finally arrived at the answer. Then, feeling rather cocky, he asked an old lumberjack how he would have done it. The old lumberjack said, "Well, I reckon I would have balanced that log on the edge of a board and sawed it off where it balanced." There are always more ways than one of doing most anything. The hardest part of the job is usually getting started.

Disproportionate Value

For the next to the last parting reminder, we would again mention that group meetings should be held regularly, and that the group leader should assure himself that instructions and explanations are thoroughly understood by allowing each employee to ask any questions about anything of which he is not sure. Instructions are often misunderstood. They may be inadvertently worded so that more than one interpretation could be placed upon them. As a homely illustration, there was a man in a small town who met a friend walking down the street about dusk with a gun in his hand. He said, "My Lord, John, what are you doing?" The friend remarked, "I've just shot a dog." This man said, "Was he mad?" His friend replied, "Well, he wasn't any too d—— well pleased."

Don't be afraid to encourage them occasionally by some sort of recognition of a job well done, a pat on the back or a word of commendation, and show your approval straight from the shoulder. Don't attempt to let a lefthanded gesture suffice. This costs nothing, and the returns are large.

Character and intelligence—that's all it takes. With an organization having these two attributes, there is no such thing as failure. Above all things, Mr. Head of a water department, try to be an inspiring leader. An employee will overlook your mistakes if you are a good fellow, but he will never forgive you for any type of unfairness. Be careful and never let an employee down, and he will rarely, if ever, let you down. One of the greatest sermons that we have ever read, applicable to employer and employee alike, is the following poem by Tom Fox, entitled, "Who Best Can Work":

"God bless those good old faithful chaps
With happy smiles upon their maps.
Whenever asked to take a job,
You never hear them squawk or sob.
Right here a phrase comes back to me—
'Who best can work and best agree.'

"To me, at least, it would appear
Two kinds of folks run this old sphere—
The birds who smile and do the work
And those who crab and stall and shirk.
That's why I say, 'God bless the guy
On whom you always can rely.'

"No matter what his faults may be,
He'll always stand ace-high with me;
And he will crash those Pearly Gates.
Not only that, I'll bet he rates
A bright and shiny golden crown—
This guy who never lets you down."

Water Supplies for the Army

By W. A. Hardenbergh

THERE are two distinct phases of Army water supply. One relates to the provision of water for troops in training in camps, forts, and posts, i.e., to fixed installations; the other, to the supply of water for troops in the field, either while training or during actual field operations. In the first, the general procedure and the equipment used are those with which water works men are familiar. In the procurement and purification of water in the field, a much different and much more difficult problem exists.

Within the past year there have been constructed or enlarged and placed in service for the Army nearly 50 large cantonments, requiring the construction of water works to provide more than 100 mgd. These works have been in operation for only a limited time and results of operation and cost data are therefore also limited. The water consumption at the different camps naturally varies, being influenced by many local factors. Average consumption is about 100 gpd. per man, varying from 65 to 135.

The provision of water in the fixed installations in this country is the responsibility of the Quartermaster Corps, the Medical Department being charged with the responsibility for inspections, recommendations and supervision of the sanitary quality of the water and for recommendations concerning quantity, pressure or other similar factors when they affect health. In Army air fields and in overseas bases, the Corps of Engineers designs, constructs and operates water supply facilities, the Medical Department having the same duties in regard to sanitary quality as it has in home camps and posts. [Since this paper was presented the responsibility for all water works construction has been placed on the Corps of Engineers.]

The quality of water for the Army is generally the same as that in the better municipal plants, it being the purpose of the Army to apply the "Treasury Department Drinking Water Standards." As in municipal

A paper presented on October 30, 1941, at the Virginia Section Meeting, Roanoke, Va., by Col. W. A. Hardenbergh, Sanitary Corps, Office of the Surgeon General, U. S. Army.

supplies, there will be instances when some variation must be made from these standards. In the Southwest, for instance, it is sometimes diffiulct to obtain water with a dissolved mineral content of less than 1,000 ppm., and salinity and alkalinity may be high, judged by Eastern standards. In regard to sanitary quality, however, no deviations are permitted.

Distribution System Design

Good practice, considered in the light of municipal standards, has been adopted by the Quartermaster General in the design of distribution systems. Cross-connections and dual systems are restricted rigidly so that waters of poor and of good quality, when available in separate systems, cannot become mixed to cause dangerous contamination. Where there are two systems, pipe lines of different materials, each clearly marked and identified, are used. Valves are installed at intervals of 1,200 to 1,500 ft. on main supply lines and on all primary branches. Hydrants are located approximately 400 ft. apart and so placed that each building can be reached from two hydrants with a maximum length of 250 ft. of hose. Special attention is given to provide accessibility to the hydrants by pumpers. Fire protection is based upon two concurrent fires with a flow, at the remotest points, of 1,000 gpm. for each fire. In smaller areas, one fire flow of 1,000 gpm. is provided for. Air release and vacuum valves are installed at high points on long supply lines. Pumping is normally by electricity, and gasoline stand-by pumps have a capacity of 50 per cent of the normal daily requirements. Storage is provided in an amount not less than 50 per cent of the total daily consumption, and not less than 50 per cent of the total storage is in elevated tanks.

Basic allowances of 100 gpd. per man, 150 gpd. per man for armored divisions and hospitals, and 25 gpd. per animal are provided for in design. Mains are designed on the basis of 250 gpd. per person, plus a residual pressure of not less than 30 psi. using a Williams-Hazen C value of 100.

Regulations provide that all mains and storage reservoirs be sterilized by standard methods after construction and before use. Laboratory equipment, apparatus and supplies are provided for each plant, the completeness of the equipment depending upon the type of treatment and the size of the plant.

Field Water Supplies

The amount of water that is required by an army in the field varies greatly with conditions, but may be estimated per man as follows: in combat, minimum for 2 or 3 days, $\frac{1}{3}$ to $\frac{1}{2}$ gpd.; normal in combat and minimum in bivouac, 1 gpd.; normal in bivouac, 3 to 5 gpd. for drinking and cooking; in temporary camps, 5 to 20 gpd.; in field hospitals, 25 gpd.;

in semi-permanent camps, 30 gpd. The amounts required for horses and mules vary from 3 to 5 gpd., minimum for a short period, to 10 gpd. per head. Water consumption per motor vehicle will be $\frac{1}{8}$ to 1 gpd., depending upon terrain and size of vehicle. In fixed camps, each shower bath can be considered to use 300 gpd., each toilet 40 gpd., each urinal 40 gpd. and each lavatory 20 gpd., but much depends upon the number of personnel using the fixtures, the temperature, and the restrictions on the use or wastage of water, commonly called the water discipline.

Prior to the World War, it was assumed that troops in the field would be able to obtain their water supply from springs, streams and wells. The American Expeditionary Force in France found that this was not possible and that local supplies generally were barely sufficient for civilian populations. Therefore, it was necessary to set up an organization to provide water to the armies in the field. Under present day conditions, with a greater dispersion of troops and a hitherto unbelievable rapidity of movement, it seems possible that once more the bulk of the water required by an army must be obtained from local supplies. The limited distance that water can be hauled from supply sources in the rear of the army area to the front lines, and the difficulty of making contact with a mobile front-line organizations, make the World War method of supply practically impossible. For instance, the Second Army in the Louisiana maneuvers was spread out over an area 75 mi. wide and 100 mi. deep. Under such conditions, the fixed water point 2 or 3 mi. in the rear of the battle line, with supply to the combat units by mule-drawn water cart, working during the hours of darkness, is no longer usable, in part because there is, in many cases, no definite battle line.

Mobile Purification Equipment

To meet the new conditions of warfare, two types of water purification equipment are available. The mobile purification unit consists of a rapid sand filter, with the necessary pumps and chlorinating equipment, mounted on a large truck. The capacity is 60 to 70 gpm. as a filter, but when the water is clear and only chlorination is necessary, the capacity is increased to 100 gpm. The chief handicap of this unit is its weight, about 17,000 lb., which restricts its use to hard roads. The portable unit is a pressure filter, skid-mounted, weighing about 700 lb. With a surface area of about $1\frac{1}{2}$ sq. ft., it has a rated capacity, as a filter, of about 12 gpm., and as a chlorinator, about 20 gpm. It is carried, with pumps, canvas tanks and other equipment, on a 1- or $1\frac{1}{2}$-ton trailer or truck.

The present organization equipment for water supply and water treatment for the field army is essentially as follows: One engineer water supply battalion is assigned to each field army. The equipment of this

unit consists of nine mobile and six portable water purification units and 135 500-gallon motor tank trucks. In addition, each Division Engineer Regiment and each Corps Engineer Regiment has three or four portable water purification units. Therefore, in the typical field army, there are about 45 portable purification units in addition to those that are a part of the equipment of the Water Supply Battalion. The intention is to provide one portable filter unit for each combat team in each division. Experience gained in the Louisiana maneuvers indicates that more filters may be needed.

Where local supplies of water are available, the Water Supply Battalion furnishes water to army troops, about 20 per cent of the total personnel of the Army; the other 80 per cent is supplied through the portable units that are a part of the Divisional and Corps Engineer Regiments. This will be normal procedure—the hauling of water from rear areas by means of the tank truck being necessary only in arid areas where local water supplies are not available.

The responsibility for field water supply lies with the Corps of Engineers and with the Medical Department. The Corps of Engineers provides the equipment and operates it, while the Medical Department furnishes the supervision necessary for the production of safe and attractive water and may also aid in training the men to operate the filters, to select water points and water sources, and in similar ways. The intention is to make each unit as nearly self-contained as possible and to avoid the necessity of hauling water over long distances under the difficult conditions of modern warfare.

Warfare Gases in Water Supplies

From time to time in newspapers and technical magazines, reference has been made to the danger to municipal or other water supplies from contamination by warfare gases, such as mustard gas, arsenic gas or lewisite, which has some of the elements of both mustard and arsenic. While it is doubtful if a concentration of such gases, sufficient to cause injury to health, could be placed in a reservoir adequate in capacity to serve a good sized city, it is possible that the fear or panic created in a community by even a small degree of contamination would be of great public health importance. Experience has shown that under such conditions many people will refuse to use a safe water and will resort to wells, springs or other sources of supply that may be dangerously contaminated. With this in mind, several years ago research was started on a co-operative basis between the Medical Department of the Army and the Chemical Warfare Service, field work being performed by the Chemical Warfare Service's technical employees and by officers of the Sanitary Corps of the

Army. As a result of this work, methods have been developed to remove the contamination due to warfare gases in concentrations that may be expected in such cases by means of usual water works equipment and materials, and with relatively slight modifications from usual filtration procedures. Where filters are not available, removal is more difficult, but still possible. These methods have been developed and outlined and, if occasion should arise, will be furnished in detail to water works plants. In the meantime, it is not believed that this is a problem of any great importance to municipal water works and their superintendents and operators.

The problem may be more serious and difficult to handle in the case of field water supplies for an army in combat. Even under those conditions, where the degree of contamination may and probably will be much higher than would ever be likely to occur in the case of municipal supplies, treatment methods are available whereby the water can be made safe and, if desired, entirely palatable. The treatment that would be necessary would reduce to some extent the capacity of the equipment provided for treating the water, but would eliminate the necessity for hauling in all water that the army would need.

Relatively simple tests have also been devised to determine the concentration of the various warfare gases mentioned, as well as others, and by animal feeding experiments, safe limits have been determined for the drinking water content of mustard, lewisite, soluble arsenic, arsene and similar gases.

Protection of Civilian Supplies

It is difficult to advise water works men on the protection of water supply installations against malicious damage. The author's personal feeling is that the danger has been overestimated and given too much publicity. There are, however, some areas in which essential defense activities are being carried on, where the water supply, because of its importance in industrial activity and for fire protection, health and convenience, is vital. In such cases, all reasonable precautions should be taken for its safety, especially where there are vulnerable points which are easily damaged but repaired or replaced with difficulty. Those areas having no essential defense importance do not seem to offer any real inducement to sabotage. The principal danger to guard against would seem to be the emotional or irresponsible individuals that are sometimes moved to do unpredictable things.

Some publicity has been given the possibility of contaminating water supplies by the introduction of bacteria or of poison. While this possibility should perhaps be borne in mind, the danger seems remote.

Treatment processes, if properly applied, should care for bacterial contamination, and the relatively large quantities of poison that would be needed to produce any serious results appear to eliminate the possibility of such use.

Knowing his own plant, a water works man will recognize better than anyone else what points, if any, should be watched to prevent damage and how careful a watch is necessary. Aside from such factors, there are, of course, many things that the water works superintendent and operator can and should do to safeguard his plant. In general, these are the things that he should do in normal times to insure a safe, efficient and reliable treatment plant or supply system, but which are too often left undone. Most of these represent only standard good practice and are known to all of us, but unfortunately, have been neglected because of lack of money or time, or inability to get around to accomplish them. Today priorities may interfere with doing some of these things, but in most plants there are still possible numerous improvements that require only forethought and the application of good administrative and technical procedures.

Within the limits of available personnel, the engineering divisions of the state departments of health will no doubt assist in determining those improvements that are most important and in making detailed recommendations for procedures when needed. In general, however, it is sufficient to say that most water works superintendents know by now what they must do to safeguard their systems and that what remains is to proceed with the execution of these plans.

Cross-Connection Control

Committee Report

THE Committee on Cross-Connections, established in 1930, presented a progress report in 1931, an extensive report in 1932 (1) and a second and shorter report in 1934 (2). Finally, in 1940 the Chairman presented informally a statement relative to the status of cross-connection control (3). The present report is designed to supplement these previous reports with new data and discussion of new problems, but without undue repetition of the earlier reports.

Between the point at which a water supply enters the distribution system and the point at which the ultimate consumer draws water for drinking, there may be opportunities for pollution and possible infection. The potential hazards may be grouped into three main classes:

1. Pollution of the general distribution system as a result of improper construction or faulty operation.

2. Pollution by "back-flow connections" or through "inter-connections" with plumbing fixtures, waste water disposal piping systems, or equipment conveying or containing harmful liquids or non-potable water or water subject to pollution.

3. Pollution through cross-connections with other supplies.

As the first two potential hazards constitute the subject of investigation by other committees, the Committee on Cross-Connections has confined its activity and attention to the third of these hazards. Cross-connections between public supplies and industrial supplies have long been the subject of discussion, papers and committee reports. Much the same ground has been gone over time and again. The reasons for and against such cross-connections have been pointed out in great detail and to enter into an elaborate discussion of the well-known aspects of the problem seems undesirable and unnecessary. A limited amount of discussion is called

---

A committee report presented on June 26, 1941, at the Toronto Convention by E. Sherman Chase, *Chairman*, Consulting Engineer, Metcalf & Eddy, Engineers, Boston, Mass.

for, however, to bring the subject up to date and to crystallize the views of this Committee.

Terminology

To avoid confusion, definitions of certain terms to be used in this report are:

Potable, with reference to water, pertains to water of safe, sanitary quality and approved for human consumption by the health or water authorities having jurisdiction.

Non-potable is the term applied to water which, without treatment, would be unsafe for human consumption.

Unapproved supply means a water supply which has not been approved for human consumption by the health or water authorities having jurisdiction. Many unapproved supplies used in industrial and in private fire protection work are unsafe for human consumption. Some well supplies, although of safe sanitary quality, may be unapproved supplies in that they do not come under control of the public health or public water authority having jurisdiction over the public supply.

Cross-connection was defined in the 1932 report and the Committee adheres to the original definition as modified by the addition of the words "or unapproved supply." The modified definition reads: "A cross-connection may be defined as any physical connection by means of which water may flow between a public or private potable supply and a non-potable supply or an unapproved supply."

Previous Committee Work

The 1932 report discussed cross-connections between public water systems and private non-potable systems used to supply water for industrial use and private fire protection purposes, and also such other cross-connections as occasionally occur within public systems or through connections for sewer flushing. The contamination of public supplies through cross-connections was discussed in detail.

In reference to manufacturing use and plant fire protection, the 1932 report gave as reasons for cross-connections: (1) the probability of occasional interruption and failure of public supplies; (2) the cost of public water for industrial purposes; (3) the inadequacy of public supplies; and (4) the inadequacy of private supplies.

The original report reviewed the policies of various state health authorities and the attitude as expressed by committees of other interested organizations. Various means of eliminating cross-connections and a résumé of experiences with protective devices was set forth, together with recommendations for control measures.

Industrial and Fire Protection Supplies

Although supplies for industrial use and fire protection were covered in detail in the earlier report, some additional discussion is now in order. The sources of adequate and reliable water supplies for industrial use and private fire protection purposes may be divided into four general classes: (1) public water supply only; (2) private water supply only; (3) public and private water supplies furnished through separate piping systems; and (4) public and private water supplies furnished through common piping systems.

To make available quantities of water as may be required in excess of the capacity of the public or private supply, or a combination of both, and to provide the desired reliability of supply and the required high pressure, recourse is made to the use of elevated tanks or ground storage from which industrial or fire protection pumps may take suction. No cross-connection, as defined in this report, can exist where the only water available within the property is supplied by Methods 1 or 2, although an undesirable condition may be created sometimes where the operation of a booster pump directly connected to public mains reduces the pressure in the water works distribution system to a low or negative pressure. This condition can, in large measure, be avoided by proper selection of pump capacity to take into account not only the capacity of the public water supply mains, but also the maximum demands thereon, including industrial or fire protection requirements of the plant.

The third method of supplying water requirements through independent services, one public and one private, separately piped, should of itself not introduce a cross-connection problem. There are, however, two phases to this method of supply which might introduce indirect hazards: first, the danger of workmen carelessly or willfully using the unsafe supply for drinking purposes; and, second, the possibility of accidental or willful connection of the two systems within the premises without knowledge of proper authorities.

The first phase is not of direct concern to the management of the public water works and in many instances does not come directly under the jurisdiction of state public health authorities. The second phase, however, is one in which the water works authorities are vitally concerned because of the possibility of contamination of public water through such surreptitious connections. Water works authorities cannot be expected to extend their supervision to include protection of the occupants or employees of the property from their own carelessness or the carelessness of fellow workers, but the protection of the general public is their responsibility.

The Committee is of the opinion that where services from the public distribution system enter properties with separate non-potable or unapproved industrial or fire protection supplies consideration might well be given to providing double check valves of the approved type, regularly inspected and maintained, on the services from the public mains. It should be pointed out that it will be necessary for manufacturers of valves to develop suitable designs for dependable check valves in the two- and three-inch sizes. Positive separation would result from the provision of protection similar to methods for elimination of cross-connections, given in the 1932 report, such as requiring that the potable supplies be furnished through an air gap into an overhead or ground storage tank from which the potable water would be distributed. Some protection also would be afforded if the pipes carrying polluted water were painted a distinguishing color, e.g., red, to lessen the chance of accidental connection of the two systems.

The fourth means of making available water for industrial and fire protection purposes, i.e., the combination of public and private supplies furnished through a common piping system, presents the greatest of cross-connection hazards. It is to this field that the greatest attention has been directed by the water works and public health authorities, and much has been accomplished in the elimination or protection of cross-connections. In many instances the need for auxiliary water supplies originated many years ago at a time when public supplies, in general, were not thoroughly reliable nor adequate to provide at all times the desired quantities for industrial use or fire protection. Inadequacy of the sources of supply, the use of small sized mains, improper reinforcement of the grid systems and lack of adequate storage were the principal reasons for public water deficiencies. The use of check valves, and later the installation of double check valves, on public water connections made available the full benefits of the public systems for industrial and fire protection use and still enabled the use of secondary supplies in the event of failure of the public systems or where quantities were required in excess of the capacity of the public systems.

Normally, the reliability of a suitable supply is the principal need of industry for process purposes and it is seldom that quantities in excess of the capacity of the public supply must be held instantly available for industrial use. Cross-connections, therefore, should seldom be needed with secondary industrial supplies. Consequently, new cross-connections with industrial supplies should be prohibited and existing cross-connections permitted to remain only in the most exceptional circumstances and, then, only through double check valve installations and subject to the approval of the water works and state health authorities.

Fire protection, on the other hand, requires both reliability and volume of supply at all times. Fortunately, public water systems, in many instances, have attained a high degree of adequacy and reliability, and such systems as a whole are sufficient to provide adequate fire protection for many classes of business and industrial properties. Due, however, to some unusual fire hazard created either by the location, construction, size, height or occupancy of a property, there may, even in the larger communities, be instances where there is need for a greater quantity of water than can be supplied from the public system. In such instances and particularly in the case of high value properties, where assurance of a continuously reliable supply of water is required for fire protection purposes, the problem of the auxiliary water supply is introduced.

The provision of reasonably adequate quantities of water for private fire protection can be accomplished in new plants by making available secondary supplies of potable water in ground storage tanks to supplement the primary supply normally available from direct connections to the public water mains. Another method for protection of new plants is the utilization of elevated storage of limited amount in combination with pumps from an inexhaustible suction supply, without cross-connections to the public supply, which would serve a limited number of hydrants only. With any of these arrangements the total fire supply would not be the equivalent in strength and reliability, particularly for large properties, to that obtainable by the dual use of public water and inexhaustible pump suction supplies.

Double Check Valves

In existing industrial plants, the lack of space for adequate storage and the cost of changing the plant fire protection system to provide protection comparable to that available through cross-connections serve as deterrents to the accomplishment of complete severance of potable and non-potable supplies. Where conditions are such that the immediate elimination of cross-connections would involve undue fire risk to life and property, they may be permitted temporarily if double check valves of an approved type are installed in readily accessible pits, so designed as to facilitate inspection and testing. Double check valve installations should be equipped with the necessary gages, gate valves and other appurtenances required for proper testing and should be entirely of bronze, especially designed with wide clearances for the clappers, provided with molded rubber facings to assure tightness, and provided with slotted bolt holes in the covers to facilitate inspection. Regular inspection and testing are essential, as is prompt correction of defects.

The establishment of any new direct cross-connection between potable

water lines and a fire line carrying polluted water, should be prohibited as a matter of general policy. The inspection records of double check valves on permitted cross-connections over a period of many years show that proper types of double check valves properly installed and maintained afford a high degree of protection. It must be recognized, however, that both valves *may* leak and cause pollution of the potable supply if they are not of the proper type properly installed and properly maintained.

Fire Pump Chlorinators

Tennessee and New York permit cross-connections with automatically chlorinated auxiliary supplies. In both states, the use of fire pump chlorinators is approved only under special conditions where the source of the auxiliary supply is not so grossly polluted that the water cannot be effectively chlorinated and, further, only in conjunction with the use of the approved type of all-bronze double check valves properly installed and equipped.

Although in New York, chlorination of the auxiliary supply is considered as rendering that supply "potable" under the provisions of the state sanitary code, installation of chlorinating equipment on the secondary supply, arranged to start automatically when the secondary supply goes into service, further reduces the cross-connection hazard, but the protection afforded is not equal to that provided by the complete severance of the two supplies. Daily reports to, and frequent inspections by, the water or health authorities, as is the practice at Utica, N. Y., render the hazard of chlorination failure less serious than where such practice is lacking.

Adequate Public Supplies

Cross-connections with auxiliary or secondary private supplies become unnecessary when the public supplies meet all needs. A. C. Hutson (4) indicates that the National Board of Fire Underwriters, for the past 35 years, has recommended and advocated improvements to insure the adequacy and satisfactory distribution of water supplies for fire protection. The latest edition of the Underwriters' standards for the installation of sprinkler equipment (5) contains the following requirements:

"Every automatic sprinkler system shall have at least one automatic water supply of adequate pressure, capacity and reliability. . . . The necessity for a second supply will depend on various factors. . . .

"A connection from a reliable water works system, of adequate capacity and pressure, is preferable as a single or a primary supply."

The same thought is expressed in the final report of the Committee on Cross-Connections of the New England Water Works Association (6) where it is stated:

"So far as possible steps should be taken in each community to provide public water supplies of sufficient adequacy and reliability, even to providing a secondary potable supply if necessary, so as to eliminate the necessity for cross-connections of any kind."

Contamination Through Cross-Connections

The many examples of contamination and infection of public water supplies as the result of cross-connections with polluted supplies are well known and have been given in previous reports of this Committee and in numerous technical papers. Within the past year, there have occurred two noteworthy examples of such contamination, in one of which an outbreak of gastro-enteritis followed.

At Gloucester, Mass. (7), polluted harbor water, used for industrial purposes, was accidently pumped into the city mains. Salt water in the mains was reported quickly to the water department, which immediately thoroughly flushed the mains and notified the state health department. Investigation disclosed the source of the pollution and the cross-connection was removed. Fortunately, the pollution was localized and the prompt remedial measures helped prevent any disastrous results.

On December 11, 1940, the same day as the Gloucester incident, contamination of the domestic water supply of Rochester, N. Y., was brought about as a result of the accidental opening of a gate valve on a connection between the domestic system supplied from Hemlock Lake and the municipally owned high pressure Holly fire system pumped from the polluted Genesee River (8). In spite of prompt remedial measures such as flushing and disinfection of the mains, about 34,000 persons in Rochester and vicinity became ill with gastro-enteritis immediately following the contamination of the public supply. Fortunately, only six definite cases of typhoid occurred and one of these was probably of secondary origin.

High Pressure Fire Systems

In view of the unfortunate experience at Rochester, a canvass was made of the municipalities, reported (9) as having high pressure fire systems. Data from this canvass are given in Table 1 and in the abstracts of replies presented below:

Atlantic City, N. J.

The high pressure supply is the municipal supply, with cross-connections to seven hotel (deep-well) supplies, which are regularly analyzed in the city laboratory. It is not possible to pump from the high pressure system into the general system. The high pressure system is entirely separate.

Baltimore, Md.

The high pressure supply is not from an unsafe source. The only connection between the high pressure system and the general system is at the pumping station, where the suction side of the fire pumps is connected to the general distribution system.

TABLE 1

Data on Municipal High Pressure Fire Systems

MUNICIPALITY	UNSAFE AUXILIARY SOURCE	CROSS-CONNECTIONS	SAFEGUARDS	TEMPORARY CONNECTION BY HOSE
Atlantic City	No	Yes (hotel well supplies)	—	No
Baltimore	No	Regular supply	Filtered and chlorinated	—
Boston	Yes	No	Good	Not probable
Buffalo	No	Regular supply	Filtered and chlorinated	—
Cincinnati	No	Regular supply	Filtered and chlorinated	—
Cleveland	No	Regular supply	Filtered and chlorinated	—
Detroit	Yes	No	Good	Possible, not probable
Jacksonville	Yes	No	Good	Possible, not done
Miami	Yes	No	Good	Possible, not done
Milwaukee	Yes	Yes	Double check valves	No
New York*	No	Regular supply	Good	Possible, not done
Oakland	Yes	Yes	Double check valves	Possible, not done
Philadelphia	Yes	No	Good	Possible, not done
Providence	No	Regular supply	Filtered and chlorinated	—
San Francisco	Yes	No	Good	Possible, not done
Toledo	Yes	No	Good	Possible, not done
Toronto	Yes	No	Good	Not possible
Winnipeg	No	Regular source	—	—

* Manhattan high pressure system—connection to river, but not used for 33 years. Brooklyn and Coney Island have pumping stations on the high pressure systems with suction connections to salt water, which, however, have never been used.

The high pressure distribution system is of steel pipe with a special flanged joint and the general distribution system is of cast iron. It would be difficult to make a connection.

Leon Small, Water Engr., Bureau of Water Supply, Baltimore Dept. of Public Works, writes: "A connection can be made between the fire de-

partment high pressure system and a fire hydrant connected to the water mains of this Bureau, but, in our opinion, there would be no reason for doing this; and as a matter of fact, it has never been done."

Buffalo, N. Y.

The source of the high pressure fire supply is the same as that of the domestic supply, which is treated water.

"Although it is possible, it is highly improbable, not to say impractical, that conditions would arise to necessitate pumping from high pressure system to the domestic system through hydrant connections."

Cincinnati, Ohio

C. Eberling, Supt. of Water Works, makes the following statement: "Our high pressure system, which is in the basin of the city, is fed by gravity from our Eastern Hills Service, which generates a pressure of approximately 180 lb. in the high pressure system. This water is all filtered and treated water and is the only source of supply to the high pressure system; there is no possibility of admitting raw water."

Cleveland, Ohio

The source of supply for the high pressure fire system is the public water supply mains. The high pressure pumping station contains pumps which draw water directly from large water supply mains serving the general system.

Detroit, Mich.

The following information is furnished by Andrew T. Dempster, Asst. San. Engr., Detroit Dept. of Health:

"You are quite right in assuming that the source of the high pressure supply is an unsafe one, since it is pumped from the Detroit River, with no chlorination or treatment to render it safe. Naturally, the existence of such a system creates a hazardous condition which the Health, Fire and Water Departments of this city have recognized for some time.

"The Fire Department laid all of the lines in the high pressure fire system, and the Water Department laid all the city water distribution system. Both departments have recognized the danger of inter-connections, and we believe that there is no connection between these two systems. The existence of the two systems creates a hazardous condition, of course, since building fire systems and fire fighting equipment could be fed from both if precautions were not taken. However, the Fire Department has provided a safeguard at every point where this could happen, and we believe that under present circumstances they are sufficient to

prevent any contamination entering the city water system from the high pressure system.

"A brief description of the system will indicate the conditions that are dangerous and the measures taken to lessen the hazard. The high pressure fire system consists of 20 miles of 8- to 20-inch pipe located in the downtown area where most of Detroit's high buildings are situated. A low static pressure on this system is constantly maintained by the head afforded through a make-up tank riding on the system. This is located on the third floor of one of the downtown fire stations. All leakage, which amounts to about 12,000 gallons a day, is replaced by city water added through an atmospheric air gap into the make-up tank. It is then necessary to operate the river water pumps at the high pressure pumping station during a downtown fire.

"In order to test for leaks in any section of this system, city water is used from a standard fire pumper, but the suction of this pumping unit is connected to a portable tank which is supplied with city water through another atmospheric gap. Gland seal water and priming water at the pumping station is also supplied to a storage tank through an atmospheric gap. We believe these are the only permanent places that city water could normally come in contact with the high pressure system, and the physical breaks between the systems at these points prevent any contamination from entering the city water system.

"There is, of course, a possibility of making a cross-connection in each building in which there is a siamese connection on the street for supplying the building fire system. However, the size of these connections is $2\frac{1}{2}$ inches and all of our high pressure hose equipment has 3-inch fittings. This would necessitate the use of an adapter to make this connection, and these adapters are not a common piece of equipment in the Fire Department. The danger of their use has been impressed upon the Fire Department, so that they have given us their written assurance that under no consideration will they use these adapters unless such a serious break should occur to the city water distribution system during a fire that it might become necessary to use them, and at that time they would only use them after notifying the Department of Health and the Water Department of the necessity. This necessity, we hope, will never materialize unless we have an earthquake or some other unforeseen condition.

"Also, there is always the danger of supplying high pressure fire fighting equipment with city water and river water at the same time. There again, the use of an adapter would be required, and the same assurances have been given to us by the Fire Department in this respect as were given in the case of siamese connections. This also applies to your last question, in which you asked if the high pressure system through hydrant connections could be connected to the city water mains.

"We also have the problem of fire boats pumping into the high pressure system through headers for that purpose, but their equipment has $3\frac{1}{2}$-inch hose fittings, which would make it difficult for them to pump into any other hydrants than the $3\frac{1}{2}$-inch fittings on the headers, without the use of an adapter.

"The only weak link in this whole system is the use of adapters by inexperienced firemen without the knowledge of their superiors. At present we feel we are pretty safe on this score, but, of course, constant vigilance is required to prevent any disregard of these rules in the future when changes in personnel occur. For that reason we have recommended that the high pressure fire system be supplied with city water instead of river water and there is a possibility that this will be considered seriously in the near future. This would not completely eliminate cross-connection possibilities unless the fire boats were completely discontinued. This also appears to be a possibility."

Jacksonville, Fla.

The high pressure supply is obtained from the St. Johns River, which is highly polluted. There are no cross-connections between the general public system and the fire system.

Data regarding the possible existence of cross-connections are quite accurate. Inspections and tests are made at frequent intervals to prevent them. It is possible to pump from the high pressure system through hydrant connections into the mains, but this is not done.

Miami, Fla.

As the source of the high pressure supply is wells and the water is not tested or chlorinated, the source should be considered unsafe. There are no cross-connections between the general public system and the fire system. The Chief Engineer of the Fire Department is very positive in his statement that there are none. No work may be done on the high pressure system without the authority of Chief Engineer, and he will be very careful to prevent cross-connections.

The only possible way to pump through hydrant connections would be deliberately to connect hoses from pumps into both high pressure and general supply hydrants, "and this obviously would not be done."

Milwaukee Wis.

The high pressure supply is from an unsafe source. There are cross-connections between the general public system and the fire system. It is definitely known that eight such cross-connections, between city and river water, exist. These are equipped with double check valves and given rigid monthly inspection.

It is not possible to pump from the high pressure system through hydrant connections into mains connected with the general supply.

Moline, Ill. (Factory Fire Main)

The source of supply for the factory pumps is unsafe. There are cross-connections between the factory fire main and the city mains. The factory main is supplied with city water, but there are provisions for the factory pumps to pump into this line.

All connections to this fire main are recorded on maps. No changes are permitted until passed upon by the various factory representatives and superintendent of the water department. Cross-connections are double checked.

It would be possible to pump from the factory fire main through hydrant connections into the city mains but under present conditions there would be no reason for it. The factories would never be permitted to start their pumps and pump through hydrants into the city mains.

New York, N. Y. (Manhattan System)

The high pressure supply is not from an unsafe source. Croton and Catskill water is used entirely. There are cross-connections between the general public system and the fire system, through the pumping stations and at two Catskill shafts. All connections are well known, controlled by check valves and standard gate valves, and operated by skilled men. No connections are permitted to the high pressure mains from any private property.

It is possible, by using hose, to pump from the high pressure system through hydrant connections into mains connected with the general supply, but it is not done as both receive water from the same source. The high pressure system has connections with a salt water river supply at the two pumping stations. Valve controls also exist. No salt water has ever been used in the 33 years the system has been in service.

Oakland, Calif. (East Bay Municipal Utility District)

"The Oakland high pressure fire system obtains its supply normally direct from the mains of the District's distribution system through an installation of double check valves designed for the protection of the public supply. In case of the failure of the public supply, water for the high pressure system can be obtained by pumping from Lake Merritt, a polluted salt water supply, or by pumping from the Oakland estuary, an arm of San Francisco Bay, also a polluted salt water supply.

"Only one connection exists between the District's public supply and the high pressure fire system. This, as stated above, is protected by double check valves which are inspected at intervals of approximately

six months and tested for leakage. There are no other connections between the two systems. However, it is possible to make a hose connection between a fire hydrant on the high pressure system and a fire hydrant on the District's distribution mains. This has never occurred. The Fire Department is advised that any such connection will not be permitted and a representative of the District is on hand at all fires and one of his duties is to see that no such connection is made."

Philadelphia, Pa.

"Suction of the Delaware and Race Street station is directly from raw water of the Delaware source. Suction of the Fairhill station is from reservoir fed above maximum water level from filtered source. The distribution system is inter-connected." There are no cross-connections between the general public system and the fire system. The Bureau of Water daily samples water in numerous locations throughout the city and analyses are made to determine bacteria and *Esch. coli*.

"Insurance agencies of the Mutual Association offer their inspection for Water Bureau information. . . . Close to 200 lb. pressure is provided and hose connections are made for discharge direct from hydrant nozzles. Pumpers are attached to the low pressure hydrants attached to the domestic or filtered water system of piping. Strict orders are maintained in Fire Department that no connection from high pressure hydrants be made to steamer connections projecting from buildings."

Providence, R. I.

"Providence has two systems, one known as the Low Service system and the other identified as the High Service system. . . . Approximately 75 per cent of our entire consumption is served by the Low Service system and 25 per cent is pumped into the High Service system. . . . Both the Low Service and the High Service systems receive their supply from the Main Scituate Reservoir, and all water discharged from the plant is purified."

San Francisco, Calif.

"The high pressure fire system in San Francisco is designed to take water from the bay through two pump stations which pump the water directly into the fire mains. The bay is a badly polluted source of water. However, the salt water has seldom been pumped into the high pressure system as the system is normally kept full of fresh water from the municipal system."

So far as is known, there are no physical connections between the piping of the two systems. "There is slight possibility that anyone would have

connected to the piping of the high pressure system mistaking it for a domestic water pipe." The Fire Department makes or allows no connections of any kind to the high pressure system, except fire hydrants. High-pressure fire hydrants are of a different style from the domestic hydrants and are distinctly marked.

"It is possible to discharge water from the high pressure system through hydrant connections into mains on the domestic system. This could be done by connecting fire hoses to hydrants of both systems. General practice indicates that this has never been done."

Toledo, Ohio

"Toledo has two separate systems for water supply. One is filtered water and the other is unpurified river water. There is no connection of any type between these two services. The pressure in the mains containing filtered water is 75 lb. as it leaves the pumping station, while the pressure in the high service system is maintained between 150 and 300 lb. which is required for fire protection purposes only. It is usually the plan to introduce pressures approximating 300 lb. when this station is in service and to regulate the delivery of water at the hydrant or hydrants which may be in use at the time of a fire. The only possible way of connection between the two systems would be from one hydrant to another, and, of course, such a procedure would have to be planned in advance and the danger would be well known to all concerned."

Toronto, Ont.

The high pressure supply is from an unsafe source. There are no cross-connections between the general public system and the fire system. The high pressure fire line is an entirely separate system with no possible cross-connections. It is not possible to pump from the high pressure system through hydrant connections into mains connected with the general supply.

Winnipeg, Man.

The high pressure supply is taken from the same source as the domestic supply. There are three connections between the general public system and the fire system, but all water is treated with chlorine. Conditions are accurately known. There are three connections only.

Safeguards to prevent cross-connections are not required, as both supplies are safe. It is possible to pump from the high pressure system through hydrant connections into mains connected with the general supply, but it is not done.

Summary

Of the 23 cities in which separate fire mains are reported, information was obtained relative to all. In the case of New Bedford, Lowell, Lawrence and Moline, the high pressure fire mains are under the control of the mills and are not public systems. At Atlantic City the high pressure system is supplied by hotel fire pumps deriving their supplies from deep wells. Of the remaining 18 cities, 8 have high pressure systems supplied from safe sources, usually the normal supply of the city pumped into high pressure mains. Ten cities report unsafe sources used to supply the separate fire mains but in only two cases are the fire and domestic systems cross-connected, and then through double check valves. Even with double check valves, however, the Committee considers such connections hazardous to health.

Fire *vs.* Pollution Hazard

Protection of the public from illness and death resulting from infected water supplies is the primary objective of cross-connection regulation and control. It must not be forgotten that, in the U. S., fire now takes a toll as great as, if not greater than, does typhoid. Directly or indirectly, according to the Crosby-Fiske-Forster *Handbook of Fire Protection* (9) some 10,000 deaths result annually from fire.

It is of course problematical how many lives are lost in fires as the result, direct or indirect, of inadequate water supply—probably not a great many. On the other hand, it is true that uncontrolled fires offer a hazard to life as well as to property. Bearing this fact in mind, health authorities must recognize that protective measures against fires serve also in some degree to save life.

1941 Status of Cross-Connection Control

During the early part of 1941 data were collected from the states of the U. S., the District of Columbia, the territories of Alaska and Hawaii, and from the provinces of Canada. These data, supplemented by data obtained in 1939 and 1940, are given in Table 2.

In general it may be said that not much change has taken place in the matter of state regulation of cross-connections since the 1940 summary (3).* There continues to be a considerable lack of uniformity of policy among the several states and provinces. Practically all the state and provincial sanitary engineers oppose cross-connections between potable

* A digest of cross-connection regulations by various state and provincial health departments was submitted as part of this committee report, but has been omitted in publication for purposes of economy.

TABLE 2

Cross-Connection Data—1941

STATES AND PROVINCES	CONTROL		CHARACTER OF CONTROL IN ENFORCEMENT*			EXPERIENCE WITH DOUBLE CHECK VALVES				POLICY REGARDING DOUBLE CHECK VALVE INSTALLATIONS			
	Under definitely established rules and regulations	Under general powers	Good	Fair	Poor	No experience or none reported	Generally satisfactory	Definitely unsatisfactory	Detailed and accurate records	Disapproved or prohibited	Permitted under special conditions	Permitted with fire pump chlorinators	No expressed policy
Alabama		X		X		X					X		
Arizona		X	X					X		X			
Arkansas	X		X			X				X			
California		X	X				X				X		
Colorado		X	X				X				X		
Connecticut	X		X						X		X		
Delaware	X				X	X					X		
Florida	X			X		X				X			
Georgia		X	X			X					X		
Idaho		X	X					X		X			
Illinois		X		X		X				X			
Indiana	X		X						X		X		
Iowa	X		X			X				X			
Kansas	X		X			X				X			
Kentucky	X			X		X				X			
Louisiana		X	X			X				X			
Maine	X		X						X		X		
Maryland	X		X				X				X		
Massachusetts	X		X						X		X		
Michigan	X			X		X				X			
Minnesota	X		X			X				X			
Mississippi		X			X	X					X		
Missouri	X			X		X				X			
Montana	X		X				X				X		
Nebraska		X			X	X				X			
Nevada		X		X		X					X		
New Hampshire	X		X				X				X		
New Jersey	X		X				X				X		
New Mexico		X		X		X							X
New York	X		X				X					X	
North Carolina	X		X			X				X			
North Dakota		X			X	X							X
Ohio	X		X			X					X		
Oklahoma	X		X			X				X			
Oregon	X		X					X		X			
Pennsylvania		X		X		X					X		
Rhode Island		X		X			X				X		

* Committee's interpretation of information furnished in replies.

TABLE 2—*Concluded*

STATES AND PROVINCES	CONTROL		CHARACTER OF CONTROL IN ENFORCEMENT*			EXPERIENCE WITH DOUBLE CHECK VALVES				POLICY REGARDING DOUBLE CHECK VALVE INSTALLATIONS			
	Under definitely established rules and regulations	Under general powers	Good	Fair	Poor	No experience or none reported	Generally satisfactory	Definitely unsatisfactory	Detailed and accurate records	Disapproved or prohibited	Permitted under special conditions	Permitted with fire pump chlorinators	No expressed policy
South Carolina	×		×			×					×		
South Dakota		×	×			×				×			
Tennessee	×			×		×						×	
Texas		×		×		×							×
Utah		×		×		×				×			
Vermont	×			×		×					×		
Virginia		×		×		×					×		
Washington	×			×			×			×			
West Virginia	×				×		×				×		
Wisconsin	×		×				×				×		
Wyoming		×		×		×				×			
Alaska	×			×		×							×
District of Columbia	×			×		×				×			
Hawaii		×		×		×					×		
Alberta		×		×		×					×		
British Columbia		×		×		×							×
Manitoba	×			×		×							×
Nova Scotia		×		×		×					×		
Ontario	×		×			×					×		
Prince Edward Island		×		×		×							×
Quebec	×			×		×					×		
Saskatchewan		×		×		×					×		
Totals	33	26	27	27	5	41	11	3	4	21	29	2	7

and non-potable supplies. Some engineers refuse to approve double check valve installations under any condition, while others will permit such connections temporarily where already installed, although withholding approval in the case of newly proposed connections. Some of the engineers who will not approve temporary use of double check valves have had no direct experience with them.

In industrial states and provinces like Massachusetts, Connecticut, New York, New Jersey, Ontario and Quebec, the attitude of the health authorities is apt to be less rigid than in the western agricultural states.

This difference of attitude is probably quite justifiable, inasmuch as in the older industrial states the practice of cross-connecting public and private supplies became established long before its danger was recognized. As a result, the health departments in these states have a more difficult task than those departments in states with fewer and newer industries. It is usually easier to prevent than to cure. It is less difficult to avoid the establishment of a bad practice than to correct it after it is once widely accepted.

In any program of cross-connection control what is practicable must be considered as well as what is ideal; in some states they are the same. In states with few industries and those few, of relatively recent establishment, it is comparatively easy to prevent the first cross-connection. This situation illustrates the difficulty of establishing rigid, nation-wide regulations. It is a difficulty, however, which does not preclude the Committee from recommending certain ideal policies as goals to be attained, although in individual states modifications of such policies may have to be made to secure any results whatever.

The attitude of the fire insurance interests has been touched upon in the reference to Hutson's article (4). The 1941 report of the Committee on Public Water Supplies for Private Fire Protection of the National Fire Protection Association (10) definitely puts that association on record as being opposed to the establishment of new cross-connections and further opposes the provision of fire department pumper connections where it is evident that the suction supply for the fire department pumpers, boat or automotive equipment would be from an unapproved source.

Effect of National Defense Program

Any current report dealing with water supplies for private or public fire protection would not, at this time, be complete without reference to the national defense program and to the possible effect on it of the adoption of any recommendations which might temporarily or permanently result in reducing the adequacy or reliability of such supplies. A great many of the industrial plants throughout the country are engaged in production vital to the national defense program and are operating close to capacity. Extensive additions are being made to existing plants and large new plants are being erected. Coincident with this industrial development, there results an increased demand for water for fire protection purposes. To supply such increased quantities of water as are necessary, extensions to existing public systems are required, and in some instances major changes in the distribution systems must be made. In a period of rapid expansion the tendency is ordinarily for public water improvement to lag behind

industrial development, which at least temporarily results in a limited and not always reliable water supply for fire protection purposes.

Water works managers and operators are giving much thought to ways and means of providing increased quantities of water such as might be required in the event of the use of incendiary and high explosive bombs. Based on experience in England, it is the general opinion that every available water supply should be conserved and made available for use during and after a bombing raid. Public distribution systems are vulnerable to bombing and under the interruptions which would result from damage by bombs, auxiliary water supplies would constitute a major, if not the only water service. Under such circumstances as might result from the use of incendiary and high explosive bombs, the hazard to life by fire is greatly increased.

Although the problem of fire protection in defense industries deserves the most careful deliberation when severance of important auxiliary sources of supply is under consideration, it must not be overlooked that an outbreak of water-borne disease in a defense industry or in an industrial community may constitute an even greater menace to the defense program than a destructive fire. In any event, care must be taken to avoid displacing one hazard by another.

Recommendations

The Committee recommends the adoption by the Association of the following expression of policy with respect to cross-connections:

1. No new cross-connections should be permitted between potable supplies and non-potable or unapproved supplies. Existing cross-connections should be eliminated in the shortest practicable time, but where immediate elimination is impracticable, such connections should be made only through approved, all-bronze, double check valves, properly installed, regularly tested, periodically and thoroughly inspected, and cleaned and repaired when necessary.

2. In cases where industrial or other establishments have separate supplies of potable and non-potable water distributed through independent systems of piping, without known cross-connections, consideration might well be given to providing double check valves, as described above, on the service pipes leading from the public mains. This would mean the development of improved designs for check valves in the smaller sizes more reliable than those now available. In any event, the pipes of the two distribution systems should be painted distinguishing colors to reduce the chance of making cross-connections through ignorance.

3. High pressure public fire systems, when supplied from non-potable

sources, should have no direct connection with the domestic supply mains. During the present period of national emergency, however, the continued use of existing systems now cross-connected may be tolerated if the protection afforded by the approved type of double check valve installation is provided under authorization by the appropriate water and state health officials.

4. Fire protection programs should not include pumping from polluted sources into public mains through hydrant connections.

E. Sherman Chase, *Chairman*
J. Walter Ackerman
Joel I. Connolly
M. W. Cowles
F. M. Dawson
Earl Devendorf
R. P. Farrell
H. E. Halpin
J. Arthur Jensen
W. Scott Johnson
W. J. Scott

References

1. Report of Committee No. 8 on Cross-Connections. Jour. A.W.W.A., **25:** 396 (1933).
2. Report of Committee No. 8 on Cross-Connections. Jour. A.W.W.A., **26:** 1836 (1934).
3. Chase, E. Sherman. Present Status of Cross-Connection Control. Jour. A.W.W.A., **32:** 1737 (1940).
4. Hutson, A. C. Auxiliary Water Supplies for Fire Protection. Jour. A.W.W.A., **33:** 972 (1941).
5. Standards of the National Board of Fire Underwriters for the Installation of Sprinkler Equipments, as Recommended by the National Fire Protection Association. NBFU Pamphlet No. 13 (July, 1940), p. 8.
6. Final Report of Committee on Cross-Connections. J.N.E.W.W.A., **43:** 90 (1929).
7. Kingsbury, F. H. Salt-Water Pollution of the Gloucester, Mass., Distribution System. J.N.E.W.W.A., **55:** 230 (1941).
8. Devendorf, Earl. The Pollution and Emergency Disinfection of Rochester's Water Supply. Jour. A.W.W.A., **33:** 1334 (1941).
9. Crosby, E. U., Fiske, H. A. and Forster, H. W. *Crosby-Fiske-Forster Handbook of Fire Protection.* Natl. Fire Prot. Assn., Boston (9th ed., 1941).
10. Report of Committee on Public Water Supplies for Private Fire Protection. Proc. Natl. Fire Prot. Assn., **35:** 167 (1941).

Legal Responsibility of Minnesota Municipalities for Polluted Water

By O. C. Peterson

ONE of the most firmly established principles of municipal law is that a municipality is liable for damages resulting from its negligence in the discharge of "proprietary" functions, but not in the discharge of governmental functions. This distinction, while simple in statement, has been exceedingly difficult to apply. It has been severely criticized by scholars and judges, both on theoretical and practical grounds. No one seems to have been able to give an adequate explanation for it; the reason for it is lost in history. As a matter of fact, the Minnesota court has itself admitted that it cannot be adequately explained. In spite of the fact that this governmental-proprietary test is difficult to explain and harder to justify, however, the cases leave no doubt of the fact that the distinction is so firmly imbedded in judicial precedent that it cannot be pried loose except by legislation. There will undoubtedly be a tendency to expand the classification of proprietary functions whenever hitherto unclassified activities are before the court for classification, but there is little likelihood that much change will be made in the existing classification.

While the court has not attempted a critical analysis of the doctrine, it has stated it on innumerable occasions. The general idea underlying the decisions is that, in carrying on certain duties termed governmental, a municipality acts as an agency of the state. Since it discharges these duties for the benefit of all, it shares the immunity of the state for whom it is acting. These duties are imposed on municipal corporations by the state for public good and they as corporations receive no benefit from them. Conversely, to be proprietary, a duty must relate to the local or special interests of the municipality.

Fortunately, as far as the subject of municipal responsibility for impure water is concerned, the distinction is not crucially important. Some functions of government have never been allocated by the Minnesota court to

A paper presented on October 9, 1941, at the Minnesota Section Meeting, Minneapolis, by O. C. Peterson, Attorney, League of Minnesota Municipalities, Minneapolis.

one or the other of these two groups, but others have been definitely placed and the utility function is one of them. Water, gas and electric utilities, when municipally owned, are clearly placed in the proprietary group, and this is true whether or not a profit is earned from their operation. As the Minnesota court said in the leading case on the subject:[1]

"The city operates the water works for profit in the sense that it is voluntarily engaged in the same business, which, when conducted by private persons, is operated for profit. The city itself makes a reasonable and varying charge; the undertaking is partly commercial. It is enough that the city is in a profit-making business. The city is exercising a special privilege for its own benefit and advantage, notwithstanding a portion of the water is used by the city for protection against fire and in promoting the public health."

The only situations which give rise to difficulty in applying the governmental-proprietary test in the field of municipal water supply are those where the portions of the water works system used in fighting fires—hydrants, mainly—have given rise to the claim for damages. In one case[2] the household goods of the plaintiff were destroyed by a fire when the fire department could get no water for an hour after being called, because the hydrant was clogged. The court found for the defendant in a suit for the value of the goods, on the ground that, insofar as the city maintained a water plant and service for use by its fire department in extinguishing fires, it was performing a governmental function. On the other hand, in a case decided fourteen years later,[3] the city was held liable for damages due to a gas leak although there was some evidence that the leak was in the pipes furnishing gas for street lighting, which has been held in Minnesota to be a governmental function. This case is difficult to differentiate from the earlier decision, but, in view of this and later cases holding consistently against the municipal corporation in cases involving utility operations of a municipality, the strength of *Miller v. City of Minneapolis* as a precedent may now be open to question. As a matter of fact, in almost all these cases of mixed governmental and proprietary functions, the Minnesota court has exhibited an almost invariable tendency to impose liability. This is, perhaps, a reflection of dissatisfaction with the immunity doctrine which, although too well settled to permit judicial abrogation, can be mitigated in effect in these cases by leaning heavily on the proprietary nature of the action or non-action which has resulted in injury. Other courts have been divided on the question of municipal liability due to defective hydrants, some holding that there is liability and some that there is not. Most cases have fallen in the latter group.

[1] Keever *v.* City of Mankato; (1910) 113 Minn. 54, 129 N.W. 158, 775.

[2] Miller *v.* City of Minneapolis; (1898) 75 Minn. 131, 77 N.W. 788.

[3] Brantman *v.* City of Canby; (1912) 119 Minn. 396, 138 N.W. 671.

Because it illustrates so well the technical refinements the courts are sometimes obliged to make in trying to apply the distinction between governmental and proprietary functions, this portion of the discussion might well be closed by mentioning a case[4] in a somewhat different, but related field, where the plaintiff was injured through the negligence of a street flushing crew of the city. The court drew a distinction between cases where flushing of a street is authorized and done solely for the comfort and health of the general public and where it is not done primarily in the interest and promotion of the public health, but in the discharge of the general duty of caring for the streets, even though it is incidentally beneficial to the public health. The function of street maintenance, by the way, has been held to be an exception to the general rule; it has been placed for purposes of liability as if it were in the proprietary class. Only in the former cases, that is, where the sprinkling is done in the interests and promotion of the public health, would the municipal corporation be exempt from liability. After examining the Duluth charter provisions, the court concluded that in that case the flushing was to keep the street in a safe condition for travel and not primarily for public health. There is an implication, therefore, that where the street is merely sprinkled to lay the dust, as in the case of the old sprinkling wagon, the city is not liable for its negligence; but if an injury occurs from street flushing, the city is ordinarily liable.

Coming back again to the field of water supply, it may be said that for practical purposes, the rules of tort liability are virtually the same for municipal water works as for privately-owned water companies. That is virtually a corollary of the proposition that a municipal corporation in engaging in the function of supplying water to its inhabitants is performing a proprietary function. The main difference in liability occurs with respect to a notice of claim statute applying to municipalities, a point which will be mentioned later. Otherwise, what will be said during the rest of this discussion applies pretty largely to both municipal and privately-owned water systems.

Factors Determining Liability for Damages From Negligence

In all negligence cases, several factors must be present before liability may be imposed. In the first place, the courts usually require that the defendant must owe to the plaintiff a duty of using due care and that he must have violated that duty. So far as the owing of a duty to the injured party is concerned, the application of that rule need give little trouble in connection with municipal water supply systems because, in the ordinary case at least, the municipality owes a duty to its customers and to the public generally to use due care. The courts usually say that the degree of care

[4] McLeod *v.* City of Duluth; (1928) 174 Minn. 184, 218 N.W. 892.

required is that of a reasonable man under the same circumstances, and this, of course, is a question of fact for the jury to determine. The municipality is not an insurer; in other words, it is not held to an impossible standard, but is simply required to be free from negligence. There is at least one exception which will be mentioned later. No time need be spent, then, on what constitutes negligence because this will vary with each individual case, and one person is as good a judge as another of whether a particular kind of conduct constitutes due care.

Another significant factor in determining liability is that the municipality's negligence must be what the courts call the "proximate cause" of the injury to the plaintiff. Speaking rather loosely, this means simply that there must be a direct causal relationship between the negligence and the injury. An old example of the application of the rule is in the story of the horse which was badly shod by a blacksmith. As a result, while the horse was walking home through the woods with his master on his back, he began to limp more and more badly. Partway through the forest a tree fell down and injured him and the rider. A suit was brought against the blacksmith on the ground that if he had done a careful job of shoeing the horse, the limp would not have developed, the horse's pace would not have been slowed down, and the place where the tree fell would have been safely passed some time before the occurrence of that event, and consequently there would have been no injury. It was said, however, that the blacksmith's negligence was too remote to charge him with responsibility for what happened. It is pointless for us to discuss in detail the doctrine of proximate cause. It is a very difficult test to apply and a good deal has been written about it by legal scholars. There is an extensive article in the *Minnesota Law Review*, for example, devoted solely to a discussion of the doctrine of proximate cause as applied by the Minnesota courts.

Another important element in liability and negligence cases is that the plaintiff must not have contributed to the injury by his own negligence. A man driving his automobile on the wrong side of a road can hardly complain legally when his car is struck by another traveling 75 miles an hour—assuming, of course, that he is in any condition to complain on this earth after such a crash. The question of contributory negligence like that of the negligence of the municipality is ordinarily a fact question in each case. Here, again, the standard is what a reasonable man would do in the same circumstances.

Liability of Municipality for Supplying Impure Water

This discussion of general principles leads to the more specific problem of municipal liability for supplying impure water to consumers.

The courts generally agree that one who sells food at retail by implication warrants that the food is fit for consumption. Since liability for failure to

observe this requirement is based on contract and not on tort, there is no necessity for proving negligence. Efforts have been made in a number of cases to apply this same rule to the sale of water by municipalities or private water companies, but, generally speaking, the courts have held that no such implied warranty exists. One of the best statements of the general rule may be found in a Wisconsin case,[5] in which the court said:

"No reason is perceived for saying that a mere distributor of water for a compensation should be held liable as a guarantor of its quality. It is not a commodity kept for sale in the strict sense of the term, but is free to everyone, in nature's reservoir, like light and air. It is taken directly or indirectly from a common source of supply. The immediate source, as in this case, is usually selected in advance and fixed by contract, leaving the mere service of the carrier to be performed, of taking the water from such source and distributing it to the consumers. To say that the person or corporation performing that service shall be burdened with an implied warranty of the quality of the same carried and distributed, would be treating the transaction as a sale, strictly so-called, and then applying an exception to the doctrine of caveat emptor not supported by any good reason or authority we are able to find, or any to which our attention has been called. It would burden such public service in a way that would be destructive of private enterprise in that line, and render public enterprise in the same direction so attended with dangers as to discourage a service that has become a necessity in all communities of any considerable size and which promotes to a high degree the welfare and happiness of individuals in communities great or small. If distributors of water under public franchises be held strictly accountable for the exercise of ordinary care not to place before their customers an unwholesome article under circumstances liable to induce persons, in the exercise of ordinary care, to use it for drinking or other domestic purposes in ignorance of the dangers attending the use, and held liable for deceit in such transaction and the law be firmly administered along those lines, the safety of individuals, as affected by public water service, will be as well promoted as is consistent with the continuance of such service, whether performed by strictly public or by quasi-public agencies."

In one case[6] which went to the highest New York court a few years ago, an attempt was made to bring the sale of water under the sales act with regard to the warranty of purity, but the court found there was no such warranty for two reasons: In the first place, a municipality does not know the particular use of particular portions of the water taken, a large part of which is not used for drinking purposes at all. In the second place, consumers do not rely on the municipality as a warrantor but realize the risk

[5] Greene *v.* Ashland Water Co.; (1898) 101 Wis. 258, 77 N.W. 722, 43 L.R.A. 117.

[6] Caravan *v.* City of Mechanicsville; (1920) 229 N.Y. 473, 128 N.E. 882.

which attends its consumption. However, there was a strong dissent in that case to the general effect that a municipality has ample means of determining the absolute purity of the water it furnishes, that a consumer places even greater reliance on a municipality than on a private person, and that public welfare demands that a municipality warrant the purity of the water it supplies.

This dissent has not yet become the accepted rule but it is not unlikely that eventually a municipality will be considered as a warrantor of the purity of water. The Minnesota court has not yet considered this problem.

While there still is no liability in contract for a failure to provide pure water, it is clear in this state and most others that a municipality is bound to use reasonable care and diligence in providing pure and wholesome water that is free from any infection or contamination which renders the water unsafe and dangerous to individuals or unsuitable for any domestic purposes. It is liable for injury resulting from its failure to do so.

The leading case on that question is a Minnesota case[7] previously cited. There the complaint charged that the city negligently allowed the supply in its water works system to become polluted with poisonous substances and large quantities of filth and sewage came in to saturate its water supply, as a result of which a consumer contracted typhoid fever and died. The defendant city demurred to the complaint. The court, however, held that the municipality was liable for its negligence. The court said in that connection (p. 62): "It is obvious that a sound public policy holds the city to a high degree of faithfulness in providing an adequate supply of pure water. Nor does it appear why its citizens should be deprived of the stimulating effects of the fear of liability on the energy and care of its officials; nor why a city should be exempt from liability while a private corporation under the same circumstances should be held responsible for its conduct and made to contribute to the innocent persons it may have damaged."

This case is the only one in which the question of municipal liability for furnishing impure water has been before the Supreme Court of Minnesota. Supplementing the information of this decision it will be well to cite a few illustrative cases from other jurisdictions which are pertinent to the discussion.

In 1908 a California appellate court was confronted with a case where a water company furnished water for a boiler used in operating a laundry. It was held that the company was obligated to use such appliances, in connection with its pipe system, as would effectually prevent the water supplied by it from returning through the feed pipe to the mains and thus causing pollution. On the other hand, the court pointed out that one receiving water from a company which also supplied that commodity for

[7] Keever *v.* City of Mankato; *supra.*

domestic purposes had no right to use the feed pipe for the purpose of relieving the boiler in his laundry of excessive pressure; that he must provide in connection with the boiler, safety appliances for the escape of steam. The court also said that if the company put in a check valve, knowing that the plaintiff was using the feed pipe to relieve his pressure, and failed to notify him of the installation, the company would be liable for the damages sustained through the bursting of the boiler because of installation of the check valve.[8]

In *Boguski* v. *City of Winooski*[9] the city was sued for damages resulting from death from typhoid caused by pollution in the municipal water supply. The city tried to defend itself from liability on the ground that the river water which caused the pollution got into the municipal supply system through a bypass which was maintained wholly for fire fighting purposes. The city maintained that since fire fighting was a governmental function, there was no liability. The court, however, held against the city on the ground that the negligence did not arise from the use of that bypass for fire protection. The court said that that part of the defendant's water business, which consisted in supplying the inhabitants with water for domestic purposes, was private in character, and, for the negligent handling of it, the city is held to the same responsibility as an individual or a private corporation. Incidentally, the court in that case went on to point out that since there was no guarantee of purity, liability would be imposed only if the city were negligent.

About three years ago a water commission in New Jersey was sued by a hotel to recover damages to a plumbing system caused by excessive sand in the water which required cleaning and repair of the system. The water containing the sand came exclusively from deep water mains which led to the hotel's plumbing system. In that case[10] the court held that there was liability on the part of the water utility for damages resulting from sand in the water as well as for furnishing polluted water. It also held that actual knowledge by the water company of the condition of the water was not necessary; that it was necessary only that the water company, in the exercise of reasonable care, should have discovered the condition. It can be said that on this point the court was applying an accepted rule.

The question of the effect of an attempted avoidance of municipal liability by contract was raised in an old case[11] decided by the Texas Court of Civil Appeals. There the city followed the practice of requiring the consumer to absolve the city from liability for negligence as to the quality or quantity of water furnished as a condition of giving service. A customer

[8] Bourie *v.* Spring Valley Water Co.; (1908) 8 Cal. App. 588, 97 Pac. 530.

[9] (1936) 108 Vt. 380, 187 Atl. 808.

[10] Seiden *v.* Passaic Valley Water Com.; (1938) 16 N. J. Misc. 301, 199 Atl. 420.

[11] Dittmar *v.* New Braunfels; (1899) 20 Tex. Civ. App. 293, 48 S.W. 1114.

could avoid this waiver, but, if he did so, he had to pay a rate that was at least double the normal rate. The court held this to be an unreasonable regulation which could be enjoined by the customer. It said also that probably the injured consumer could have sued for damages and these unreasonable contracts waiving liability would be ignored. The court held the double rate contract was discriminatory and the company could not compel the plaintiff to enter into it.

A cursory search has revealed no other cases involving this kind of attempt to avoid liability through a contract with the consumer, but, on the basis of decisions in somewhat analogous situations, it seems that the same rule might be applied in Minnesota. The Minnesota court has sustained reasonable rules and regulations of a municipal water utility, such as a rule requiring shut-off in case of delinquency;[12] but it is doubtful whether the court would place a rule of the kind involved in the Texas case in the same category.

A different situation might be presented, however, if the city were to attempt to avoid liability through home rule charter provision. In the case of *Schigley* v. *City of Waseca*,[13] the court had occasion to construe a home rule charter provision to the effect that an action for damages resulting from a defect in the street could not be maintained unless the municipality had been given written notice of the defect at least ten days before the accident happened. As can be seen readily, this provision drastically restricted municipal liability in this field, but the court sustained the provision, saying: "A right of action against the municipality is thus a matter of legislative favor, and may be granted absolutely or conditionally. When it has been held to exist by implication, it may be taken away by the legislature, without violating any constitutional right of the individual. Obviously, then, the right of action may be made to depend upon compliance with certain conditions." The court went on to say that the city, by home rule charter, had the same power as the legislature in this regard. It is possible that the court would differentiate from that kind of provision, a charter provision which denied any right to bring an action against a municipality for damages sutained as a result of the furnishing of impure water by the city or village. It might say that this is an absolute prohibition of the action and also that it involves a purely business or proprietary function with respect to which a municipality may not limit its own liability any more than a private corporation can. Yet the court has sustained a notice of claim statute with respect to municipal utility accidents, and this clearly gives a municipal utility a special advantage over privately owned utilities carrying on the same business. It is, therefore, quite possible that

[12] Powell *v.* City of Duluth; (1903) 91 Minn. 53, 97 N.W. 450.
[13] (1908) 106 Minn. 94, 118 N.W. 259.

a municipality could, by home rule charter, abrogate its liability for torts in connection with the operation of its water works; but it is believed that no city has yet attempted to include so drastic a provision in its charter; and such an exemption from tort liability might not be sound in principle.

It has been said that a municipality is liable for damages resulting from a polluted water supply if the pollution is due to its own negligence, but what is the standard of fitness to be applied? Must the water be fit when it comes out of the water faucet in the consumer's home or is it sufficient merely that it is suitable for domestic consumption at the property line? Two years ago the Massachusetts Supreme Court, one of the best courts in the country, faced this problem in the case of *Horton* v. *Inhabitants of North Attleboro*.[14] There, the water supply of the defendant municipality contained 30 ppm. carbon dioxide. This was conceded to be 10 ppm. beyond the limit of safety. The plaintiff's service pipes were lead. The defendant had rules permitting lead pipes and had approved the installation in this particular case. The plaintiff contracted lead poisoning, probably from the water supply which contained 4 to 8 ppm. Evidence showed that 0.3 ppm. was the maximum which the United States Public Health Service considered safe. The plaintiff sued for damages, both for breach of warranty and on the basis of negligence. The instructions given the lower court, which were unobjected to, assume that there was an implied warranty, so the case passed that point without any decision; but on the question of where the test of pure water is to be applied, the court said that good water at the gate was not enough. A town which knows that water supplied by it is to pass through lead service pipes must supply water which will be fit for drinking after passing through pipes, as well as at the water gate or water meter. The fact that water was fit at the property line was not sufficient. On the other hand, the court did say that a town supplying water to households could assume that the water once inside the house and subject to the householder's control would be conducted and used properly, and the town, therefore, need not investigate inside the house. The result probably would have been different had the lead pipes been used over the objection of the municipality and after the consumer had been informed of the danger of lead poisoning that might result. A recent English case[15] permitted recovery by the plaintiff under a factual situation quite similar to the Massachusetts case, where the plaintiff also put in lead service pipes. In that case, however, the water board had been warned several times that their water was harmful after it had passed through these lead pipes. It is interesting to notice an earlier English case[16] to the contrary, in which the city

[14] (1939) 19 N.E. (2d) 15.

[15] Barnes *v.* Irwell Valley Water Board; 54 L.T.R. 818.

[16] Miles *v.* Huddersfield; L. R. 12 Q. B. Div. 443.

had approved the installation of lead service pipes from its mains and the customer was poisoned by lead. The city was held not to be liable on the ground that its duty ended by supplying wholesome water in the mains.

The extent to which a municipality will be liable for impurities which come into the water supply after it has left the mains will depend to some extent, perhaps, upon the control it has and exercises over service pipes. Obviously, if the municipality constructs or maintains any portion of the line from the main to the house, its responsibilities are greater and its opportunity for liability as a result of negligence is also greater. Here, again, there seems to be some tendency to expand rather than diminish municipal tort liability.

It is questionable whether water must be fit for the use which every consumer wishes to make of it, or whether it is necessary only that it be wholesome for general consumption and ordinary industrial purposes. In a New York case[17] the owner of a dye factory sued the city for damage to its product because of the presence of chlorine in the water. Proof indicated that it was practically impossible for the dye factory to make a profit as long as that particular kind of water was furnished. The court held, however, that it was only necessary that water furnished by the city be wholesome for general consumption and ordinary industrial uses. On rehearing, the court considered the question of whether the city would be required to use another source which the city admitted by demurrer was available. That source would not require the use of chlorine but the court held that the city had no obligation to consider the needs of this individual user and could not be required to change the source.

A different situation of this kind was presented to a Georgia court in *Griffin* v. *Griffin Chero Cola Bottling Co.*[18] There, the defendant used water in the manufacture of bottled drinks. The municipal water supply contained chloride of lime which rendered unpalatable the drinks manufactured out of the water by the customer. The court said that when the municipality had knowledge that the existence of the chloride of lime would have this effect, an inference was authorized that the city was negligent in not informing the customer of the existence of the chloride of lime, and that, where the customer without knowing the unpalatable condition of the water and without being able to discover that condition by due diligence, used the water, in combination with syrups, the municipal corporation was liable to the customer for the damage thus sustained. The

[17] Oakes Manufacturing Co. *v.* New York; (1912) 206 N. Y. 221, 99 N.E. 540, 42 L.R.A., N.S. 286.

[18] (1926) 35 Ga. App. 779, 134 S.E. 812.

opinion was merely a brief syllabus opinion which did not contain the reasons for the court's decision, so it is somewhat difficult to tell whether or not the court considered that there was any implied warranty involved, but the reference to the negligence of the water company seemed to show that the action was based on tort. Presumably, the municipality would not have been liable had it pointed out to the customer that its water supply contained the objectionable chloride of lime. Even so, it is difficult to see how the plaintiff avoided a charge of contributory negligence under the circumstances.

Several cases have involved a situation where public and private water systems were connected and the check valve between them was tampered with so as to cause impure water to flow from the private water supply into the city mains. In these cases, the courts have imposed a duty on the city to inspect the valves with great care because any defect could cause extensive injury to the consumers. One case which well illustrates this rule is that of *Pennyslvania Ry. Co. and City of Ft. Wayne* v. *Lincoln Trust Co.*[19] There, the city and the railroad water systems were connected; the railroad secured impure water directly from the river and the check valve worked improperly so that the river water was poured into the city mains. One of the consumers contracted typhoid, apparently from the water. The court held that while the city had no notice of the defect, notice was not necessary since, by the exercise of reasonable care, the city would have discovered the impure character of the water and that the valve was open. The danger of impurity should have been apparent to the city. In a Washington case involving the same kind of situation,[20] the court, in holding that it was proper to submit to the jury the question of whether the city had exercised due care, said: "This is a focal point of danger and the city is required to use extreme care to see that the people are protected."

The courts would no doubt agree that there is no liability on the municipality if typhoid is contracted from water from a private well. The only ground for liability in such a case would be that the municipality had not properly carried out its duties of protecting the public health, but the function of preservation of health has been held to be a governmental function and negligence in the discharge of that function does not therefore give rise to an action for damages. Since damage from this source has nothing to do with the furnishing of water to consumers through a municipal supply, there can be no liability on the ground that the supplying of water is a proprietary function.

---

[19] 91 Ind. App. 28, 167 N.E. 721.

[20] Roscoe *v.* City of Everett; 136 Wash. 295, 239 Pac. 231, Wash., 1935.

Proof of Negligence

Previously it was pointed out that what constitutes negligence, in these cases of municipal liability for furnishing polluted water, is a fact question in each case and must be decided on the basis of the evidence presented. This is also true as to whether negligence of the municipality is the proximate cause of an injury. It is not the sort of thing about which one can say that, under a given situation, there is or is not liability, because most of those fact questions will be decided in the last analysis by a jury, whose verdict will not be overturned if there is any real basis for its decision. Here, it is intended simply to mention one or two cases which will illustrate that point.

To be entitled to damages for typhoid fever contracted from the municipal water supply, an individual must not only prove negligence on the part of the municipality, but he must also show, beyond reasonable doubt, that the water was the actual cause of his illness. In a case decided by the Court of Appeals of New York, it was held, however, that this fact may be shown "with reasonable certainty" despite a rule of law that, where there are several possible causes of injury, the plaintiff must prove that his injury was sustained by a cause for which the defendant is responsible.[21] In the New York case evidence was presented to show that the city's water supply was badly contaminated and that there was an increase of typhoid fever cases during this period. There was also medical testimony to the effect that the plaintiff's attack of the disease was due to drinking the city water. These facts were held to be sufficient for a jury's determination as to whether the disease was contracted from this or some other source.

Where, however, the legal representatives of persons who died from typhoid fever, which was alleged to have been contracted from a city water supply, failed to show, by a preponderance of evidence, that the city water was the actual source of the disease, a finding by a jury in favor of the city was upheld by the Supreme Court of Utah in 1936.[22] In that case expert witnesses for the plaintiff testified that the city water showed the presence of colon bacilli indicating contamination and that the water was responsible for an epidemic of fifteen known cases of typhoid. Experts for the city testified, however, that the water could be excluded because most of the persons having the disease had been in contact with other definite sources of infection, such as proven typhoid carriers and, furthermore, that there were comparatively few cases of the disease in a population of 40,000 all of whom used the city water.

There are some situations, such as the bursting of a water main or

[21] Stubbs *v.* City of Rochester; (1919) 226 N. Y. 516, 124 N.E. 137, 5 A.L.R. 1396.
[22] Stoker *v.* Ogden City; (1936) 88 Utah 389, 54 Pac. (2d) 849.

reservoir, where the Minnesota court imposes liability on the municipality without any fault whatever, but this is not true in actions for damages resulting from impure water. Incidentally, it is believed that the Minnesota court is almost alone in its holdings on these water main and reservoir cases.

In *Wiltse* v. *City of Red Wing*[23] a water reservoir of the city gave way and the plaintiff's property was damaged—in fact, practically ruined—because of the volume and force of the water—some 800,000 gallons of water being stored there. The court followed an established doctrine in Minnesota that a party who, for his own profit, keeps on his premises anything unnaturally belonging there, the natural tendency of which is to become a nuisance and to do mischief if it escapes, is liable if it escapes, without proof of negligence, for all damages directly resulting therefrom. The court held that the rule applied to the city for, although a municipal corporation, it was engaged in the business of supplying water to its inhabitants for profit, an undertaking of a private nature. In *Bridgeman-Russell Co.* v. *City of Duluth*[24] the supreme court decided that the same doctrine applied to a principal water main where the proof indicated that, in an hour, just as much water could go through the main as escaped from the Red Wing reservoir in the earlier case. The court carefully pointed out that this was not a case of water escaping from service pipes, an implication that the same doctrine does not apply there.

It was said, in the brief explanation of the factors necessary to liability in negligence cases, that contributory negligence of the injured party defeats recovery. Lack of personal investigation or notification to the company, however, is usually not contributory negligence. In two fairly recent cases[25] it was held that a customer is not guilty of contributory negligence because he does not personally investigate and determine whether the water is in any way polluted or contains any extraneous substance. There is no duty in those cases, said the court, to take positive action by notifying the company of the existence of a foreign substance.

In an early case referred to previously[26] it was held that, where the existence of the contamination of typhoid fever had been so generally known and realized by the public and by the individual concerned that his use of raw and untreated water amounted to contributory negligence, no recovery would be allowed against the water company. This rather harsh rule has been modified to some extent in the later decisions mentioned, in which it

[23] (1906) 99 Minn. 255, 109 N.W. 114.

[24] (1924) 158 Minn. 509, 197 N.W. 971.

[25] Hamilton *v.* Madison Water Co.; (1917) 116 Me. 157, 100 Atl. 659; Jones *v.* Mt. Holly Water Co.; (1915) 87 N. J. Law 106, 93 Atl. 860.

[26] Greene *v.* Ashland Water Co.; *supra.*

has been held that it is no part of the duty of the consumer to make investigations. It may now be said definitely that this duty rests upon the water company which must take such positive action as is necessary to determine the condition of the water supply and must exercise due care for the protection of the health of its customers.

There are still numerous situations in which use of water by a consumer may involve contributory negligence which will defeat recovery for any damages sustained because of impurities. In the dye manufacturer case,[27] cited above, the court held that, since the manufacturer knew of the impure condition of the water and that it caused damage in his process, the plaintiff could not recover damages because he was contributorily negligent in voluntarily using the water.

Notice of Claims Statute

A Minnesota statute (Mason's Minn. Stat. of 1927, Sec. 1821), which has been in force substantially in its present form for many years, provides as follows: "Every person who claims damages from any city, village or borough for or on account of any loss or injuries sutained by reason of any defect in any bridge, street, sidewalk, road, park, ferry boat, public works, or any grounds or places whatsoever, or by reason of the negligence of any of its officers, agents, servants or employees, shall cause to be presented to the common council or other governing body within 30 days after the alleged loss or injury a written notice stating the time, place and circumstances thereof and the amount of compensation or other relief demanded. No action therefor shall be maintained unless such notice has been given; or if commenced within 10 days thereafter or more than one year after the occurrence of the loss or injury."

It will be seen that there are two main classes of cases in which this notice of claim is demanded as a condition precedent to maintaining an action. The first of these is defects in any public place and the second is the negligence of any municipal agent.

This statute has been specifically applied in actions for damages resulting from impure water. In *Frasch* v. *City of New Ulm*[28] a New Ulm resident sued the city for negligently furnishing her contaminated water as a result of which she was injured. The only defect in the case was in failing to allege a notice to the city and the city on that ground demurred to the complaint. It was held that the city was entitled to notice. The plaintiff tried to make the point that the notice requirement did not apply to cases in which a municipality was carrying on a proprietary function because the result of

[27] Oakes Manufacturing Co. *v.* New York; *supra.*
[28] (1915) 130 Minn. 41, 153 N.W. 121.

such a ruling would be to give the municipality an advantage over private utilities and the court had frequently made the point that when a municipality carries on a utility enterprise, it is subject to the same rules and liabilities of private persons. The court held, however, that the statute contained no exception in favor of municipal utilities and none would be read into it. Consequently, the notice was required.

An earlier form of the notice statute contained no valid provision as to notice in negligence cases, the valid portion of the act, relating only to defects in public places. In *Winters* v. *City of Duluth*[29] the plaintiff had stumbled on an obstruction on the floor of the municipal pumping house and was injured, allegedly through the defendant's negligence. It was held that at that time under that statute that the notice requirement had no application since the obstruction was not a defect within the meaning of the statute. That case is of interest only as a matter of history, however, because this defect in the statute has since been remedied and it clearly applies now, both to defects and to negligence cases. Attention is called specifically to the broad nature of the present law because in many other states similar notice statutes are not so broad. In Montana, for example, the supreme court held, rather recently, that it was not necessary in that state for the injured person to give notice to the city of the condition precedent to maintaining an action for damages due to typhoid fever resulting from the city water supply.[30] The notice statute was also held not to apply to municipal utilities in Montana.

In connection with this notice of claims statute, it might be well to mention, to complete the picture, that the statute does not apply to such actions as nuisance or trespass, which are not based on negligence or on defects in public property. For example, no notice has been held required in cases involving the drainage of sewage on private property.[31] While those cases do not relate to the operation of a water works, they are mentioned because, conceivably, some actions against a municipality, arising out of its water utility operation, may be based on nuisance, trespass or some other non-negligent tort.

Power to Prevent Pollution

While municipalities are held to a high degree of care in the furnishing of water for human consumption, they do have power to take whatever steps are necessary to keep their water supply unpolluted. The state and municipalities, both, may adopt and enforce reasonable legislation to

---

[29] (1901) 82 Minn. 127, 84 N.W. 788.

[30] Campbell *v.* City of Helena; (1932) 92 Mont. 366, 16 Pac. (2d) 1.

[31] Joyce *v.* Village of Janesville; (1916) 132 Minn. 121, 155 N.W. 1067; Hughes *v.* Village of Nashwauk; (1929) 177 Minn. 547, 225 N.W. 898.

protect public water supplies, and in a group of statutes against water pollution, the state has done so. To prevent contamination, the state and its cities and villages may adopt legislation or pass regulations to prohibit bathing, boating and other activities in or on reservoirs and other sources of water supply, whether they are on public or private land.[32] In carrying out necessary public health measures, a municipal corporation will not be liable for injuries to persons or property resulting from its negligence. Where, for example, dairy cattle were driven from the city watershed by a city employee, who used ordinary care in doing so, it was held that the city was not liable for damages to the cattle.[33] The maintenance and operation of a water supply and the distribution of water for domestic consumption are proprietary activities of a municipality, but the protection of the water supply in the interests of the public health is generally considered to be a governmental function. No cases involving this particular problem have been tried in the Minnesota courts.

Not only may a municipality adopt ordinances to preserve the purity of its water supply but it may enjoin pollution through a court action. This is true no matter how long the pollution has continued, because no one can acquire a prescriptive right to pollute a public water supply.

In Minnesota, the State Board of Health has been given a number of powers over public water supplies. These include, in the first place, the power to adopt rules to prevent pollution. These rules have required the approval by the State Board of plans for a water works system and for the condemnation of disease-bearing water supplies. The enforcement of all the laws concerning pollution has been made a function of the State Board of Health. These laws are numerous so that, ordinarily, pollution at the source of supply is adequately prevented under existing statutes.

This survey has been able to touch on only a few of the "high spots" of municipal tort liability in connection with the operation of a water works system. With advances in scientific management of a water works, the trend will probably be to expand rather than diminish liability. Consequently, the lesson that water works men can learn from the decisions is that, for purely legal reasons, if for no other, they should use the utmost care to see that the water they furnish to consumers is free from pollution and impurities.

---

[32] Tobey, James A. *Public Health Law.* The Commonwealth Fund, New York (1939); p. 221 and cases cited in Note 37.

[33] Phillips *v.* City of Golden; (1932) 91 Colo. 331, 14 Pac. (2d) 1013.

Some Legal Aspects of Sewage Treatment

By Grover Jones

IN NORTH CAROLINA, municipalities must have legislative authority to build sewage treatment plants, the plants being built within the exercise of their governmental function. The Supreme Court of North Carolina has consistently held to the general rule that, unless a right of action is given by statute, municipal corporations are not liable for failure to perform or neglect to perform duties governmental in their nature, including generally, all duties, existent or imposed upon them by law, for the public benefit. To this general rule there is a well recognized exception, i.e., the court has held repeatedly that, where damage to land results from the operation of a sewage treatment plant by a municipality, the injury is considered a taking or appropriation of the land to that extent, and compensation must be awarded for such taking.

The court, in making this exception to the general rule, emphasizes the fact that, where a sewage treatment plant is built by a municipal corporation pursuant to legislative authority, the source of the injury is protected by legislative sanction and the predominance of the public interests. In other words, one who owns land near a sewage treatment plant, or on or near a stream that is polluted by the operation of a sewage treatment plant, cannot enjoin the operation of such plant for injuries which may happen to his land. The only recourse that such a landowner has is an action for damages sustained by reason of the taking of his land in whole or in part resulting from the operation of the sewage treatment plant. The taking is as of the date of the first substantial injury to the land and the landowner can bring suit for all damages to the land, past, present and prospective.

The rule that has been adopted generally by the courts of the several states with respect to property rights may be stated briefly to the effect that the owner of land has a right that the air which comes upon his premises shall come in its natural condition, free from artificial impurities and that this right has as its correlative obligation that one must not use

---

A paper presented on November 5, 1941, at the North Carolina Section Meeting, High Point, N. C., by Grover Jones, City Attorney, High Point, N. C.

his own premises in such a manner as to discharge, into the atmosphere of his neighbor, dust, smoke, noxious odors or other foreign matter which substantially affect its wholesomeness. The right to pure air is property, and to interfere with the right for public use is to take property. The right to pure air is the same as the right to pure water; it is an incident to the land, annexed to and a part of it, and it is as sacred as the right to the land itself.

While the courts generally hold that the pollution of air or water must substantially affect the landowner in order to amount to a taking, in whole or in part, of his land, it is a question for the jury to determine whether, in a given case, there is sufficient impregnation of the atmosphere with noxious mixtures passing over the land to amount to an invasion of a natural property right, or whether the pollution of the water as it passes by or through the land alleged to be damaged is sufficient to amount to a taking. If the impregnation or pollution is sufficient, the jury will, almost without exception, find that there has been an invasion of the natural property rights of the landowner and, thus, a taking, in whole or in part, of his land.

In the numerous cases involving sewage treatment plants, which the author has tried, he has found that landowners and their witnesses are so prejudiced against the location, operation and maintenance of a sewage treatment plant near their property, or on a stream along which they live, that they give themselves without reservation to the most reckless and malicious swearing. In many of the cases the landowners who brought suit had not visited the sewage treatment plant prior to the institution of the suit and in some instances had not done so even after their suits were brought. They knew nothing and did not care to know anything about the plant. In most instances their testimony was a revelation of the grossest sort of ignorance about the most elementary principles of sewage treatment; yet the juries paid but little attention to the expert witnesses, apparently believing everything that the landowners and their witnesses had to say. It is most unfortunate for a municipal corporation that a suit brought against it because of the operation and maintenance of a sewage treatment plant must be tried by a jury. In most instances the jury serves simply as an arbitrary method of settling the controversy between the landowner and the city and usually the verdict represents anything but justice.

In two instances the author was able to get the court to consolidate and refer cases brought against the City of High Point because of the operation of its sewage treatment plants. Unless counsel for the city and for the landowner agree to waive a jury trial upon proper exceptions to the ruling of the referee, however, the matter must be tried before a jury

upon the facts as found by the referee. A reference of such cases is very helpful to a municipal corporation, for, in most instances, the landowner is willing to accept the award made by the referee.

While the right of jury trial is guaranteed by the Constitution in cases of this kind, and cannot be taken away except by consent of the parties, it is the author's opinion that the State Legislature could vest in the State Board of Health, or in some commission, full power and authority to make certain preliminary investigations and findings prior to the bringing of any suit by the landowner. In such act the Legislature could provide that the landowner must submit the matter to investigation and report by the State Board of Health or the commission set up for that purpose prior to the bringing of any suit. Such procedure would have a two-fold benefit, in that it would tend to enlighten landowners as to the process that was employed at the particular plant for the treatment of sewage and would tend to discourage the bringing of suits in cases where there is no real basis for suit and that it would encourage municipalities to build more sewage treatment plants, as it would save them hundreds of thousands of dollars annually in the operation and maintenance of those plants.

Unless municipal corporations in North Carolina are afforded some such just protection, there is no reason why they should spend vast sums of money in building, maintaining and operating sewage treatment plants. The average municipality gets little or no credit from the landowners for building sewage treatment plants and apparently gets no credit for the endeavor on the part of the municipality to relieve the streams from pollution by providing the best methods known for treating and disposing of waste matter from the congested areas.

It would not be unreasonable for the State Board of Health to ask the Legislature of North Carolina to pass such a law as that suggested. The plans for the building of all sewage treatment plants by municipal corporations must be submitted to and approved by the Board of Health. Likewise their operation is under the general supervision of the Board as is the initiative in urging their construction. The problem, then, is more than only local in aspect; it is also state-wide in scope. For the reasons here advanced, this matter should be brought pointedly to the attention of the Legislature and the Legislature should do everything within its power to encourage the building of sewage treatment plants for the protection of the health and lives of the people of the state and for the purification of the water courses of the state.

State Engineering Aid to New Mexico Municipalities

By W. Carlos Powell

THE office of State Comptroller, whence the so-called "engineering aid" originates, is in charge of municipal accounting. Within the limits of approved budgets, it has broad powers over methods of accounting, expenditure of funds and the general business of cities, towns and villages, but why such an office or agency of government should need engineering service or make it available to municipalities is a question which is often asked. When the fact that New Mexico, with its small population, has 55 publicly owned utilities in operation or under construction and many sewer systems, of which several are actually operated as public utilities, is considered, however, the reason becomes obvious. These utilities, which include 44 water works as well as gas and electric companies, are faced with numerous problems of accounting and operation that materially affect the governmental functions of a community and that, in many cases, require engineering service.

Because the office of State Comptroller is always being called upon to make decisions relative to the transfer and use of funds for construction costs and for municipal improvements in all departments and because the utilities are contributing in no small measure to the general upkeep, through, and even outside of, regular budgetary demands, the engineering service is a very definite part of its function of office. The New Mexico Revenue Bond Act, under which, at this time, most of the new water works systems are financed and existing systems improved, has produced a field of financing that is not subject to the usual rigid requirements which control the issuance and sale of general obligation bonds, and has been accompanied by vigorous promotional activities by engineers, lawyers, bond dealers and others, resulting in a not too favorable situation.

The Comptroller's office stands ready to review any proposed plan of improvement from a technical or economic standpoint, thus giving those more vitally interested the benefit of an impartial view of the problem. It is not the intention to be arbitrary or dictatorial in such functions, but to

A paper presented on September 19, 1941, at the Rocky Mountain Section, Santa Fe, N. M., by W. Carlos Powell, Munic. Engr., State Comptroller's Office, Santa Fe, N. M.

offer to the proper authorities a means of overcoming outside or, for that matter, inside influences tending to create unsound technical and economic conditions. In New Mexico, as no doubt is true in other states, projects have been conceived and initiated, wherein improvements have been made in which the preliminary factors were not well developed. As a consequence adequate facilities were not obtained and often unfavorable financial conditions resulted. This is just one place in the general scheme of things where the Comptroller's office can contribute to the welfare of the various communities of the state. This process is, of necessity, going to be slow, not because there may not be sufficient authority to insist on the considerations given, regarding proper practice, but because there must be a reasonable period of education.

For years, in New Mexico, authorities of all municipalities have been required to prepare quarterly reports on the fiscal affairs pertaining, for the most part, to the operation of the General Fund; but, at the same time, little had been accomplished in connection with the reporting of utility operation. Ten years ago utilities were not such an important factor, as there were not so many publicly owned plants and systems, and not nearly so much incidental and miscellaneous construction throughout. Beginning in 1933, people became more conscious of public ownership and entered fields of endeavor that previously would not even have been considered. In many instances construction initiated under the various loan and work agencies has been most satisfactory as an employment and relief consideration, but dangerous to the financial standing of the municipality for one reason or another. If the proper preliminary steps had been taken in such projects, they might never have been started or, if approved, a different plan might have been more successful. Thus, it can be shown that in certain governmental plans of improvement, as well as in those sponsored and executed privately, there appears to be a need for some governmental technical agency for consultation and advice.

A specific example of the dangers that may affect the credit of a community is a case now before the Comptroller's office. In this instance, a village, with no advisory help from any state source, issued general obligation bonds, sold them to a governmental loan agency and proceeded with the construction of a water works system under another work agency. How the loan was ever secured in the first place is somewhat of a mystery, as the valuation of the community was, and is, extremely low, so that, with the debt incurred, a liability of approximately 23 per cent of the assessed value was created. To make the situation even worse, the project was designed and built under the supervision of an individual not licensed as an engineer, as the results indicate—the supply being most inadequate and the general design far from meeting standard practices.

The bond ordinances, of which there are two, provide explicitly that the net revenue of a water works system shall be used to help pay retirement charges. Consequently the budgetary authorities have attempted to lessen the tax load by anticipating a certain net revenue. The result has usually been a defaulted bond issue. The system is so insufficient in its functions as to be almost no system at all. A situation of this kind indicates that the regular constituted authorities cannot always rely on agencies other than those within and a part of the state government for the necessary assistance—thus, again, the need for state engineering aid.

State aid of this type can be and has been extended to other municipal functions, such as streets, sidewalks, etc. There is some question as to whether the Comptroller's engineering considerations will compete or conflict with private engineers in their regular practices. It is believed that this is not in any way possible except in instances where questionable propositions may arise. Instead it would appear that the reputable private engineer would gain through this set-up, as there will be a responsible agency ready to recommend the securing of engineering service where projects or conditions warrant or require it. All of this becomes more or less a repetition of the intent and scope of the program, but it will be agreed that the problem is a real one and the solution at least worth trying. Those who might be benefited can be assured of the fullest co-operation possible while those not to be assisted should not be encouraged in any event.

One other feature of engineering that is of interest to many, if not to all, at present, is that termed "Sales Engineering." Glaring examples of salesmanship in lieu of engineering may be found in many localities, and if construction and maintenance activities cannot be accomplished without being subjected to such practices, somewhere there can be expected to result a bad taste in the affairs of the communities. As an example, it is not considered fair for an engineering representative of a selling concern contacting a municipality in the hope of selling equipment or material and finding that the municipality must meet certain legal requirements as to bidding, to offer to write the specifications or prepare the plans and estimates for not only his own product but also that of the other venders of similar or accepted products. This not only confuses the technical situation so far as the prospective purchaser is concerned, but injures the private engineer and quite likely impairs the best interests of the proposed vender as well.

The intent of the New Mexico State Comptroller's engineering plan has been outlined in these pages, but it is found each day that the program broadens as new problems are introduced. For that reason it is not now possible to foresee the potential or ultimate development of this type of governmental service.

Maintenance and Protection of Elevated Water Tanks

By H. F. Stearns

IT HAS been remarked that the rusting or corrosion of steel is similar to the common cold which ravages the human race, in that it is the ill most common, most taken for granted and of the greatest nuisance to owners of elevated tanks. Often it is accepted a sa necessary evil about which little can be done. In short, the matter of corrosion and its cure is an abomination with which all water works men must contend.

In regard to the maintenance and protection of elevated water tanks, it is possible to segregate owners into two groups—Non-Maintainers and Maintainers. The *Non-Maintainers* also are of two types. First are those who, from necessity, do not maintain their tanks. These represent the few isolated cases where tanks cannot be removed from service for a sufficient time to paint the interior surfaces—the exception rather than the rule. On the other hand are those who, from choice, follow the least line of resistance and do nothing, or practically nothing, to keep their tank and tower structures in a condition that will permit a full life of usefulness. Some of the members of this group purchase a tank and completely forget about it, only to be surprised and chagrined after a period of about twenty years when they are confronted with extensive and costly repairs or even replacement. Very often the owner of an elevated tank merely paints the outside of the structure to make its appearance more pleasing to the eye of the public and the consumer. The popularity of this malpractice is surprising.

On the other hand there are the *Maintainers*, who may be segregated into four different classes on the basis of the various methods of maintenance employed:

1. Those using commercial paints of lead, zinc, aluminum, graphite and other pigment bases mixed with either oil or synthetic vehicles. Such materials are for use on both interior and exterior tank surfaces. Water works men are more than familiar with such products, due to numerous salesmen

A paper presented on May 12, 1941, at the Southeastern Section Meeting, Charleston, S. C., and on October 28, 1941, at the Kentucky-Tennessee Section Meeting, Nashville, Tenn., by H. F. Stearns, Chicago Bridge and Iron Works, Birmingham, Ala.

who overrun the country. All of them tell the same story, bursting with superlatives and never omitting their own products from the claim of perfection. In passing it should be pointed out that in recent years chemical and research workers have made notable advances in their endeavor to arrive at a more permanent and enduring commerical paint for use on plate and structural steel. As yet, however, no perfect paint has been secured.

2. Those using non-hardening inhibitors, such as grease-like and emulsified asphalt materials, for the interior of water tanks. These are slight departures from commercial painting, in that a film of material is spread over the steel surface by use of canvas-covered smoothing boards and trowels much like plastering tools. Selection of the proper types of these materials is largely dependent upon the temperatures likely to be experienced. The overall costs are about comparable with commercial painting.

3. Those using coal-tar enamels on interior tank surfaces. The application of these products is best made by the manufacturers or by workers who have, from long experience gained the skill and knowledge required for the hot-daubing procedure. Although first costs may appear high the lasting qualities usually justify these products under proper conditions of use.

4. Those using cathodic protection. This is a comparatively new and entirely different idea for protecting the inside surfaces of water containers. In the rough, this method of preventing corrosion is an electrical device. A low voltage electric current is set up in the tank shell and riser of an elevated steel tank by use of properly located electrodes, or anodes, submerged in the water. The current is adjusted in amount sufficient to maintain a hydrogen film on the inside surfaces of the tank. In other words, the tank is a cathode and, as a negative pole, attracts the positive hydrogen ions, thus preventing the active and rust-promoting oxygen ions contact with the steel. As a matter of fact, the oxygen ions are negative and therefore attack the positive electrodes which are made of extremely durable materials, replaceable at reasonable costs. It has been estimated there are over 500 installations in elevated tanks throughout the country. A few of these have been in operation for six years, several for five years, and the remainder for shorter periods. This device undoubtedly has much merit, and practical performance makes it appear deserving of consideration.

Many of the foregoing methods of maintenance and protection of tank interiors do not specify the need of caring for the underside of the tank roof, and, in many instances, the inside of the tank shell above the waterline. These parts should not be overlooked or neglected as they are the first danger signals that all is not well with an elevated tank. Usually they are the first parts of such a structure to require replacement.

Proper Maintenance

Most of this paper so far has had to do with the protection of elevated tanks. Maintenance and protection are so closely related, however, that in speaking of one indirect reference is made to the other. As a homeowner, if a downspout or gutter needs repair, you do something about it; if a sill is rotting away, you replace it; you also repaint your home periodically, say at from four- to six-year intervals. From experience you have found this the economical way. Likewise with a tower or tank structure, if it is noticed that tower rods are loose, columns or posts out of line, ladders shaky, or corrosion excessive, some competent and reliable concern should be employed to investigate the conditions and make recommendations for repair. In this connection, periodic inspections are of great importance and a good investment. The old adage, "An ounce of prevention is worth a pound of cure," applies. Tank repair experts who offer gilt-edged contracts based on payment for only such rivets as are actually cut out and redriven should be guarded against. A program such as this cannot help but develop into an endless task, because work on the faulty or leaky rivets often loosens the adjoining rivets or opens the calking edge of the plate adjacent. The final result is the presentation of an exorbitant bill. All of this sums up to a recommendation that exactly the same measure of common sense and good judgment be used in keeping an elevated tank in order as would be employed in the maintenance of a home.

The life of a steel water storage tank is a question difficult to answer due to many variable factors. These factors have to do principally with the characteristics of the water stored and climatic conditions. It has been reported that 45 years is the average life of a steel standpipe. This is based on a survey of 111 installations throughout New England and New York State, where it is generally admitted that severe weather conditions are encountered. There is no reason to believe that an elevated tank will not last an equal period of time if given proper care and attention.

Frequency of Painting

Another common question is that of how often a water tank should be painted. There are many excellent examples where tanks, in inland locations, have gone seven to ten years or more before repainting work of any consequence was required. On the other hand there are cases where newly painted structures show film failure and corrosion within three to six months when close to salt water. It is well known that light-colored and aluminum paints show signs of discoloration in very short periods if tanks are located near industrial centers where the ordinary stack belches forth either smoke, chemical fumes, or dirt in some form. It is evident from

these statements that it is difficult to strike an average for the periodic painting of a tank, but an interval of five years comes somewhere near the mark.

An important factor having to do with the life and frequency of painting elevated tanks is the preparation of the steel to receive the initial shop coat of paint. Those who have made a study of this subject claim it to be a most important part of the procedure in the installation of a tank. In short, they say the steel must be cleaned not only of grease, oil and dirt, but of all scale. This necessitates the removal of mill scale by one of the three recognized methods—phosphoric pickling, flame descaling, or sand or grit blasting. They further recommend that the steel be warm when the first paint is applied. There is still much research to be done along these lines, but it appears that phosphoric pickling is rapidly becoming accepted as the best and most economical. These remarks deal primarily with new tank projects but are worth keeping in mind for their bearing on the general subject.

This paper is merely a generalization of the topic of tank protection and narrows down to the fact that common sense must still be applied in the absence of the sought-for perfect materials and better known methods of application and procedure in maintaining and protecting water tanks.

The elevated tank is of the greatest importance in the water distribution system and fire protection of a community. It cannot be excelled as a form of storage for water, simply because no one as yet has set forth an idea or an apparatus which can improve upon the force of gravity.

Maintenance of Elevated Tanks and Standpipes

By Charles J. Leary

IN DISCUSSING maintenance of steel elevated water tanks and standpipes, it should be remembered that the structures are, as the name implies, built of a ferrous metal. The natural inclination of steel is to rust and return to the oxide. When this process is permitted to take place on a standpipe or elevated water tank, the life of the structure is curtailed, the structure deteriorates, and the original investment is rusted away in the form of corrosion which represents a definite loss in dollars and cents. It is logical to assume that if corrosion can be successfully stopped, depreciation and deterioration will be held to a minimum and, barring an act of God, the life of these structures can be prolonged indefinitely.

Before determining what to do to protect or maintain a steel elevated tank or standpipe successfully, it is necessary to mention briefly just what manner and form of corrosion is present. Various authorities have advanced different theories as to the causes of corrosion. The JOURNAL has carried many well written and complete explanations of corrosion phenomena. According to these authorities, corrosion and oxidation may take one of many forms, or a combination of two or more of these forms.

First of all, the steel must be exposed so that it comes into contact with moisture and air, which contain the oxygen necessary to all corrosion. Almost every one is familiar with the common form of rust. It is seen every day on water pipes, automobile fenders and on the surfaces of the water tanks wherever metal has been exposed. This type of corrosion is general and found on practically every water tank or standpipe, inside and out. Galvanic or electrolytic action, another type of corrosion most generally present on the interiors of tanks below the water line, is based on a theory that dissimilar parts of the metals immersed in water cause adjacent parts of the steel sheets to become charged negative and positive. The result is small electric currents which travel from one charged area to another and cause pitting of the steel. This represents one of the most

A paper presented on October 28, 1941, at the Kentucky-Tennessee Section Meeting, Nashville, Tenn., by Charles J. Leary, Universal Construction Co., Indianapolis, Ind.

serious forms of corrosion. Other conditions which may accelerate corrosion on any one structure are the pH of the water, the extent of corrosive minerals present in the water, the amount of coal dust or soot that might fall in a given period of time, the severity of the seasons and the humidity or amount of condensation on the exterior of the structure.

The estimated life of an elevated water tank or steel standpipe is from 40 to 60 years depending, of course, directly on the amount of protection or maintenance each received. These records are derived from data on structures which have been given at least a minimum of protection. One structure, however, had evidences of pitting action only five years after erection, where, upon cleaning for repainting, it was discovered that there was no paint protection left in the saucer of the tank and a few pits, which had penetrated halfway through the steel, had been formed. Another steel elevated tank had to be replaced after fourteen years' service. An examination of the record showed it had never had any interior attention. In one case, tanks inspected, for the first time, after 40 years service showed no evidence of corrosion below the water line, while, twenty miles away, another structure of the same age and with the same record of interior protection suddenly developed a hole in the saucer. An inspection uncovered more than a thousand pitted places in the bottom. These few illustrations are pointed out merely to emphasize the fact that no two of the structures can be counted on to be alike. They cannot be taken for granted and, if they are not maintained, they represent a gamble, with the odds in favor of corrosion.

Corrosion Danger Areas

There is only one way to be absolutely sure as to the condition of the structures. If the steel is protected against the various forms and types of corrosion, it will be safe to assume that the life of any structure will be indefinite. Before reviewing the methods of protecting the structure it might be well to point out the various places and parts of a steel standpipe and elevated tank which need to be watched as danger points.

These danger points are most generally attacked first by rust, and damage is more likely to multiply if the rust is neglected for even a short period. The underside of the roof, roof angles, spider rods and that portion of the side walls above the water line are subjected to extreme conditions at all times. Moisture from the water is always present and is picked up by the air and circulated continuously. Add to this the heat received from the sun beating down on the roof and an ideal condition for corrosion is set up, if the air and moisture can find an exposed bit of steel. The final result is more than likely to be the rusting away of and the necessity for patching on roof sheets, even replacing the roof. Roof rivets, too, will rust out and

roof angles and anchor bolts corrode away. In a great many cases this corrosion has resulted in erection of a new top sheet to replace the old which was eaten away above the water line.

The remainder of the interior sidewalls and bowl or bottom of the tank may have more or less corrosion present depending entirely on the corrosive index of the water and the minerals present. It will be in this part of the tank that electrolytic action may take place. If so, the steel will be pitted. Some pits may be small and insignificant while others may be quite large and deep; some may be around rivet heads and others along the seams and calking edges; whenever these pits are found to have weakened the steel they should be repaired and built up by the arc weld process. In some places, where the pits are too deep and too close together, it may be necessary to patch. The shallow pitted places should be treated so that further pitting action is stopped. In some cases it may be necessary to replace some unit of the tank where pitting is excessive. In a majority of cases, however, the pitted places can be repaired by welding. If rivet heads have been eaten away until the rivet has lost its ability to do properly the job it was intended for, it should be replaced. It may be necessary, too, to recalk some of the seams in the structure to stop small seep leaks.

Other Factors of Danger

Quite a few tanks have an extension of the riser pipe above the bottom of the tank. This acts as a mud trap and keeps any mud, silt or corrosion from entering the system. This main must be covered before any work is done on the interior to prevent foreign material from falling into the riser pipe.

Included on the exterior of the tank for inspection periodically, to insure proper maintenance, is the expansion joint. This should be kept pulled tight to prevent leakage and should be repacked every few years. In some regions, on elevated tanks with small riser pipes, it is necessary to have some protection against freezing of the riser pipe during winter months. This protection usually takes the form of a three-ply two-air-cell wood frost casing or its equivalent, designed to protect the riser from freezing in the coldest weather expected. It is advisable to keep this covering in good condition and to examine it about every five years.

Sway and stay rods should be kept tightened, usually requiring attention each five years. The stay rods are to keep the riser pipe in a vertical position and the sway rods to protect the structure in high winds. These rods are of vital importance and should not be adjusted haphazardly. When the tank is subjected to high winds it has a tendency to sway with the wind. If the rods are too loose there will be a tendency for the structure to twist. Loose rods have resulted in some tanks being twisted to the extent that the

supporting structure was damaged. This twisting will also result in the loosening of seams and rivets and consequent seepage.

The footings on an elevated tank should be kept cleaned and free from all débris which might hold moisture. If the footing is a type which has box-like steel plates at the bottom, there are drain holes which should be kept open to permit drainage of water. Care should be taken that no débris, especially coal or ashes, is piled around the legs. The entire weight of the tank rests on these footings and they are vital points. On some of these, a treatment consisting of cleaning well, coating with a rust inhibitor and flashing with asphalt, is recommended. Cement should not be used to fill these places as it will hold moisture.

On tanks with large riser pipes and standpipes, the cement grouting should be examined periodically to see that it has not chipped away and permitted moisture to get underneath the steel plates. The cement or brick foundations of elevated tanks should be examined for this also. When moisture is permitted to enter these small cracks and crevices, especially in winter, quite a bit of damage is caused by freezing. It is advisable, after a few years, to use a surveyor's level on the foundations to be assured the tank is in plumb.

The catwalks of most tanks are drilled at intervals to permit water drainage. On most tanks, however, the catwalks are not level so that the water does not drain toward the holes. Consequently the water stands in puddles until finally dried up by evaporation. This results in excessive corrosion of the catwalk and of exterior rivet heads holding the bowl of the tank where it is riveted into the first vertical sheet. Additional holes should be drilled. A good way to find out where they are needed is to examine the catwalk immediately after a rain.

On some elevated water tanks, especially the older types, numerous places where cross-struts join the legs, and around gusset plates, pockets, where water will stand, are formed. These places should be inspected carefully and drainage holes provided. All corrosion should be removed and the metal primed and painted. Any places that have begun to rust out should be reinforced or replaced with new steel.

Last but not least is the overflow pipe. Generally, this is merely a stub pipe extending a foot or so out from the tank, directly beneath the roof eaves. It serves its purpose well, but in many cases lets water splash against the sidewalls and supporting structure of the tank and causes discoloration of the paint and, in some cases, excessive corrosion. The only remedy for this is to pipe the extension below the catwalk or even to the ground. It is well to be sure this stub extension is screened or covered to prevent the entrance of birds into the tank.

Painting Practice for Corrosion Inhibition

After all these particular points have been inspected the question of what to do to combat corrosion successfully and to protect the structure arises. It must be decided what methods to follow in selecting materials for protection, what type of materials are best used, etc. It has been pointed out that, in the beginning, it is necessary for a ferrous metal to be exposed to moisture and air which contains oxygen before the corrosion phenomena can take place. It naturally follows that to halt or forestall this action it becomes necessary to cover or hide the metal surface, inside and out, from the moisture and air. The oldest and best known, time-proven and foolproof, protective coatings are paints and similarly applied products. This necessarily is a controversial subject and cannot be covered at length to each individual's satisfaction in this paper.

Each and every paint manufacturer has a "world-beater" material for underwater protection and has conducted controlled tests proving his product a superior brand. Perhaps one foolproof way to determine which material would be the best to give the maximum protection in any one tank would be to have a complete analysis of the water present in the tank, then present this analysis to a paint chemist and have him specify a particular material which would withstand and counteract all reactions which might take place in the particular tank. Unfortunately this is not a practicable way, involving too great an expense. Various coatings are recommended by the Federal government to be used under water. These recommendations include red leads, tar and asphaltic paints, special water works enamels, waxes and various types of grease coatings. Most any material which falls into these classes can be depended on to give satisfactory service.

Exterior coatings usually fall into two classes, the primer paints and finish coatings. A mixture of red lead and oil is perhaps the oldest and best known rust inhibitor. Blue leads, chromate primers, and other inhibitors, however, will give very satisfactory coverage. Finish coatings most generally have been aluminum and graphite paints with a sprinkling of others. In purchasing paints, one should exercise caution to secure an accepted brand with a first grade vehicle, as the life of the paint coat depends upon the quality of material used. The best method to assure quality material is to purchase from a reputable company and pay enough money for the material.

To secure the most satisfactory paint coat coverage it is necessary to repaint the structures before an excessive amount of corrosion has been formed. In other words, when the oils have dried out of the old paint coat and the paint has begun to allegrate and crack, exposing the metal to the elements, the structure is in need of paint coat attention. This permits the new paint coat to act as a freshening coat and utilizes the paint bond from

the previous coat. When the structure gets maintenance attention at this time it is necessary to remove all loose paint, rust scale, oil and grease by scraping, wire-brushing and wiping. Power-propelled tools are preferred, for obtaining a better job.

All bare metal places should receive a "spot coat" of rust inhibitive paint before the finish coat is applied. If the structure has not been repainted for some time, it may be necessary to apply a complete coat of primer before applying the finish coat. In most cases one finish coat is all that is necessary for proper protection. It stands to reason, however, that two finish coats will give longer protection and may or may not be applied as the operator may desire. The same method of cleaning before paint application should be given to the interior surfaces of the tank. The average life of such painting, inside and out, should be about five years, with some tanks holding up better than others, depending upon the various factors which govern the life of paint.

Before contracting such maintenance work, there are a few pertinent facts the operator or city council should keep in mind. Price should not govern the decision too much. The superior knowledge, of the man who knows how, is worth whatever extra it may cost to hire him. It took engineers to design and construct the tank and it takes someone with a concrete knowledge of the structure to maintain it properly. Some things to demand before letting a contract are proof of the integrity of the contractor, competent workmen, proper tools, equipment, and insurance. Usually a contractor, who can furnish workmen's compensation, occupational disease, public liability and property damage insurances and a bond for the job, will be able to perform a first class job. One should beware of the itinerant steeplejack and the local man who can climb and professes to be a steeplejack. Also one should beware of excessive guarantees. The operator should be sure he has safety valves to guard against the blowing up of water mains while pumping direct pressure and should make arrangements to have the tank interior sterilized after completion of work. Plans should be made to have a competent inspector of consulting engineer examine the structure to determine what, if any, repairs may be necessary at the time of painting.

In closing it might be well to repeat—steel elevated water tanks and standpipes are erected and built of a ferrous metal. Its natural tendency is to revert to the oxide. A good way to combat this is to keep the moisture and air from all steel surfaces by applying a protective coating of paint periodically. This usually necessitates repainting each five years on an average. If this program is followed it is safe to assume that the life of the structure is indefinite on the logical conclusion that if corrosion is stopped, there is no possible way for deterioration, except by an act of God.

Progress Report

American Research Committee on Grounding

THE activities of the American Research Committee on Grounding between June 1, 1940 and July 1, 1941 have been carried on by the Technical Sub-Committee in accordance with the general program outlined in its report dated June 14, 1940 (Jour. A.W.W.A., **32:** 1946 (1940)). The program, somewhat lighter than in previous years, has been affected by the war abroad and the national defense emergency, as well as by changes in personnel occasioned by the death of one member and the removal of another to take up new work.

Fewer reports of trouble where water pipes or their contents were affected and where there was any question of the trouble being due to electrical causes were received this year than in previous years. Investigations were made of all situations where complaints were referred to the Committee.

Further consideration was given to pipe test programs referred to in last year's report, and preliminary work was carried out on some of the test programs discussed therein. Renewal of activity in this work is discussed later in this report.

In previous years, the Committee has followed with considerable interest the investigations of grounding by the British Electrical and Allied Industries Research Association. During the past year, however, no reports have been received from Great Britain, due, no doubt, to war conditions.

The development of a fitting for making grounding connections to water pipes, which was discussed at the last meeting of the Committee, has not progressed, although the Committee would be pleased to receive any suggestions along this line.

Field Investigations

Inspections were made on Cases 67 through 84. The results of these investigations have been analyzed and are given in Table 1. A complete investigation was made on each case where a complaint of trouble had been

Submitted by H. S. Warren, *Chairman*, 420 Lexington Ave., New York, N. Y., and C. F. Meyerherm, *Secretary*, Pres. and Engr., Albert F. Ganz, Inc., 511 Fifth Ave., New York, N. Y.

TAB

Summary of Investigations,

CASE NO.	LOCATION	COMPLAINT	CONDITIONS OF GROUNDING		PRESENCE OF ALTERNATING CURRENT WITH TEST LOAD		PRESENCE OF DIRECT CURRENT		TYPE OF WIRING
			Neutral	Service Conduit	On Water Service	On Inside Piping	Stray	Other	
67	N. J. Seaboard	Failure by pitting of hot water tank and pipe	Water pipe	Water pipe	Yes	Yes	No	No	Non-metallic sheathed and armored cable
68	N. J. Seaboard	Same as 67	Driven rod	Driven rod	No	No	No	No	Knob and tube, some armored cable
69	N. J. Seaboard	Conflicting information	Water service	Water service	Yes	Yes	No	No	Knob and tube, some armored cable
69A	N. J. Seaboard	None	—	—	—	—	—	—	—
70	Southern N. Y.	Electric shock	None at this service	Cold water pipe	Yes	Yes	—	—	Armored cable
71	Long Island N. Y.	Blue water staining	Water service	Water service	Yes	No	No	No	Armored cable
72	Long Island N. Y.	Blue water	Water service	Water service	—	—	—	—	Armored cable
73	Long Island N. Y.	Blue water, rust	Water service	Water service	Yes	Yes	No	No	Armored cable
74	Long Island N. Y.	Blue water	Water service	Water service	Yes	No	No	No	Armored cable
75	Long Island N. Y.	Blue water	Water service	Water service	Yes	Yes	No	No	Armored cable
76	Long Island N. Y.	Occasional green staining of fixtures, rusty hot water	Water service	Water service	No	No	No	No	Armored cable
77	Long Island N. Y.	None	Water service	Water service	Yes	Yes	No	No	Armored cable
78	Southern N. Y.	Pipe failure	Water service	Water service	Yes	No	No	No	Armored cable
79	Southern N. Y.	Pipe failure on heating boiler header	Water service	Water service	Yes	Yes	No	No	Armored cable

LE 1

May 1, 1940 to July 1, 1941

WATER PIPING MATERIAL					APPARENT SOURCE OF TROUBLE	REMARKS
Mains		Service	House	Hot Water Tank		
Pipe	Joints					
C.I.	Lead	Copper	Copper	Copper alloy	See remarks	Water at times carried high CO_2 and H_2S. Hot water used at unregulated high temperature. See also 68–69A.
C.I.	Lead	Copper	Copper	Copper alloy	See remarks	Conditions similar to 67. See also 69, 69A.
C.I.	Lead	Copper	Galvanized	Copper	—	Water supply same as 67. Some hot water tube had been replaced. Tank insulated, may be copper alloy. See also 68, 69A.
C.I.	Lead	Copper	Copper	Nickel-copper alloy	—	Water supply same as 67. Thermostat on gas-fired hot water heater set at 140° F.
C.I.	Lead	Lead	Galvanized	Galvanized	Open neutral in electric service	Another failure in interior wiring provided ground for return of current through conductor enclosures and water and gas pipes.
C.I.	Leadite	Copper	Copper	Copper	Aggressive water dead end main	Water mixture treated and untreated deep well supplies. Dead end main. See also 72–77, 80, 81.
C.I.	Leadite	Copper	Copper	Copper	"	Conditions same as 71.
C.I.	Leadite	Copper	Copper	Copper	"	Conditions same as 71.
C.I.	Leadite	Copper	Copper	Copper	"	Conditions same as 71.
C.I.	Leadite	Copper	Copper	Copper	"	Conditions same as 71.
C.I.	Leadite	Copper	Copper	Nickel-copper alloy	Rusty water from dead end main	Same water mixture as 71, shorter dead-end main, individual transformer.
C.I.	Leadite	Copper	Yellow brass	Silicon bronze, 98% copper	—	Same water mixture as 71. On through main.
C.I.	—	Galvanized and copper	Yellow brass and Muntz	Reinforced copper	Season cracking	Individually defective pipe.
C.I.	—	Galvanized	Galvanized	Galvanized	Normal service life	Steel pipe at boiler. Boiler water treated, changed at least annually.

TABLE 1—

CASE NO.	LOCATION	COMPLAINT	CONDITIONS OF GROUNDING		PRESENCE OF ALTERNATING CURRENT WITH TEST LOAD		PRESENCE OF DIRECT CURRENT		TYPE OF WIRING
			Neutral	Service Conduit	On Water Service	On Inside Piping	Stray	Other	
80	Long Island N. Y.	None	Water service	Water service	—	—	—	—	—
81	Long Island N. Y.	None	Water service	Water service	Yes	No	—	—	Armored cable
82	Northern N. J.	Taste and odor	Water service	Water service	Yes	Yes	—	—	Armored cable
83	Southeastern Pa.	Green staining of fixtures	Driven rod	Driven rod	No	No	Yes	No	Armored cable
84	Long Island N. Y.	Blue water, staining	Water service	Water service	Yes	Yes	—	—	Armored cable

made. Wherever practicable investigations were also made at other locations in the immediate vicinity or related territory to determine how widespread the trouble complained of might be. In some cases where trouble had not been reported nearby, under conditions which appeared to be similar, inspections were made to determine what factors might explain the difference in behavior. These supplementary inspections have covered only points where differences might be significant. This procedure has been followed for the past year or so. As a result, the nineteen cases reported in Table 1 represent inspections in only seven localities. Investigations in three localities of particular interest are discussed below.

New Jersey Seaboard—Cases 67 to 69A

In two of these cases, complaints were made that the copper or copper alloy hot-water tanks and part of the copper tube hot-water piping had failed by pitting after only two to three years' use. In one of the cases, recently installed hot-water tubing showed signs of possible early failure. The water delivered in this community is of unusual composition in that it is extremely soft and of very low alkalinity. Also, at times, it carries very high free carbon dioxide plus hydrogen sulfide. At both locations where trouble had been reported, the domestic hot-water supplies were maintained at very high temperatures. In one of these cases both the copper tube water service pipe and much of the interior piping carried al-

Concluded

WATER PIPING MATERIAL					APPARENT SOURCE OF TROUBLE	REMARKS
Mains		Service	House	Hot Water Tank		
Pipe	Joints					
C.I.	Leadite	Copper	Copper	Galvanized	—	See cases 71-77. House located on dead-end main near untreated source. Sample taken.
C.I.	Leadite	Copper	Red brass	—	—	See cases 71-77. House located on dead end main near treated source.
C.I.	—	Copper	Red brass	Nickel-copper alloy	Study not complete	Cooled drinking water had disagreeable taste and odor—not detectable at inspection.
Spring water supply	—	Copper	Copper	Galvanized	Aggressive water	Local treatment of water suggested.
C.I. cement lined	Leadite	Copper	Copper	Nickel-copper alloy	Semi-aggressive water	Trouble appeared after dead-end main had been converted to through main.

ternating current under load conditions, while in the other case no trace of current was found on any of the piping under any condition of electrical load. In both cases the owners of the residences were advised that reducing the settings of the thermostats for domestic hot-water supply to operate at a temperature not exceeding about 140°F. would substantially reduce the corrosiveness of the hot water. At a nearby house with the temperature of the hot water so regulated, no trouble was reported with other conditions similar.

Long Island, N. Y.—Cases 71 to 77, 80 and 81

A large water purveyor derives water from two deep well sources located several miles apart. The water at both plants has a low alkalinity and is relatively high in free carbon dioxide with a pH between 6 and 6.5. At one of the plants the water is treated with lime prior to its delivery into the mains, resulting in an increase in the pH to about 7.4 and the practical elimination of free carbon dioxide. At the other plant chlorination only is used. Customers, in some parts of the territory served, generally receive a mixture of both lime-treated and untreated water, while in other parts the principal supply is from one or the other source alone. The use of copper water tube for services and interior piping has become widespread in this territory. There have been a number of reported complaints of blue water and staining of garments or fixtures from those sections receiv-

ing water largely from the untreated supply, especially where dead-end mains were involved. Inspections were made with a view to covering the variations of treated and untreated supplies, dead-end and through mains, as well as presence or absence of alternating current on the piping.

In one section where conditions seemed to be more acute, special arrangements were made to keep alternating current off the piping in two residences, while at other residences conditions were left as found so that some alternating current interchange occurred on the piping under normal electrical loads. Chemical analyses of water from these residences have been made about every two months over almost a year. The results of these analyses should give some indication whether electric current over the water piping in this territory and under the conditions of these tests has any appreciable effect in modifying the corrosiveness of the water as indicated by the copper pick-up from copper water tube. As yet no consistent differences in copper pick-up in pipes with or without current have been observed. The tests are being continued.

Long Island, N. Y.—Case 84

A complaint was made of blue staining of porcelain fixtures and clothing and blue coloring of the water, upon addition of soap, all of which began after the water purveyor had changed the dead-end main into a through main connecting to feeder mains at widely separated points. No other complaints in the town had come to the attention of the water purveyor. The mains on this street are cement-lined cast iron with "Leadite" joints. The water supply at the plant showed a pH of about 6 with a carbon dioxide content of 10 to 12 ppm. The alkalinity was low, about 15 ppm. Water samples taken at the residence where the complaint originated showed a pH of 6.7, with 7 ppm. of free carbon dioxide, and alkalinity of 22 ppm. Samples from another residence nearby which was located at the end of a 300-foot dead-end cement-lined main showed a pH of 7.3, with 3 ppm. of free carbon dioxide and an alkalinity of 32 ppm. The characteristics of the still or slowly moving water in the dead-end main were changed by contact with the cement lining. Speeding up the water flow, such as undoubtedly resulted from converting the dead-end main into a through main, reduced the contact time between the water and the cement lining. Water in the main under through conditions was evidently more corrosive in character than it had been before.

Pipe Tests

As has been indicated in previous reports (in some detail, last year), the Committee has been trying for some time to make arrangements for conducting tests on pipes subjected to various electrical conditions, i.e., some

carrying alternating current, some direct current and others no current at all. Such tests would closely parallel tests made by the Hackensack Water Company prior to the formation of the Committee. The Committee's investigations, both field and laboratory, have failed to agree with some of the conclusions drawn from these previous tests. It has, however, been impossible to make the necessary arrangements for carrying on the desired tests, the principal difficulty being to find a location where suitable facilities and properly trained personnel were available.

During the past year the picture has changed somewhat. The American Water Works Association has sponsored a program of pipe tests to be conducted at New York University, intended more or less to parallel the Hackensack tests previously mentioned, but brought up to date in the light of present day knowledge. The Technical Sub-Committee, through the courtesy of the American Water Works Association, was invited to discuss the general nature of the tests and the testing methods to be employed and to keep in touch with the progress of the tests after they began in the autumn.

A unique feature of these proposed tests is the practical application of the polarograph as a means for analyzing the water for metallic ions, both before and after contact with the various pipes. This method is reported to be very sensitive for the detection of any metallic ions in weak solutions without concentration by evaporation.

One of the simpler methods of testing for pipe corrosion mentioned in last year's report by the Technical Sub-Committee, namely, a water drip test, was set up on a trial basis during the year. Water from four coils of copper tube was allowed to drip on unglazed porcelain plates, to determine whether the scheme could be practically applied under a minimum of supervision. So far, the results have not been wholly satisfactory, but the work is still under way.

Future Work

It is proposed to continue investigations where complaints are made of water contamination or pipe deterioration and where grounding of electrical systems to water pipes is involved. The Committee repeats its request for prompt reporting of complaints of this kind in the territory within about 200 miles of the New York metropolitan area. If conditions are particularly unique or serious, the Committee might also go beyond these limits.

The Technical Sub-Committee also plans to work closely with representatives of the American Water Works Association in connection with the pipe tests already mentioned.

Corrosion Study of Bolting Materials and Coatings

By Otto A. Halvorson

HOW and why unprotected iron and steel rust or corrode has been debated among technical men for a good many years. Today, although differences of opinion still exist as to the full explanation of this phenomenon, what is known as self-corrosion, based on the electrochemical theory, seems to be established on the firmest basis and to have the widest acceptance.

In this paper the author will deal principally with a case of self-corrosion of iron and steel bolting materials and comments on protective coatings. In doing this, it may be well, first, to confine the discussion to the basic principle of this type of corrosion. In this relation, F. N. Speller offers a logical explanation:*

"Iron, like all other elements, has a definite inherent tendency to go into solution when placed in contact with water. Iron, however, can enter solution only by displacing some other chemical element already in solution. For instance, a piece of iron placed in copper sulfate goes into solution, but, at the same time, copper is plated out and appears on the surface of the iron. In the ordinary case of iron immersed in water, hydrogen is the element plated out. This hydrogen gathers on the surface of the iron in the form of a thin, invisible film.

"The presence of this film tends to obstruct or congest the progress of the reaction by insulating the metal from the solution. This interference may become so effective in natural waters as to stop corrosion altogether; thus, the first stage of corrosion comes to a stop so quickly that no appreciable damage is done to the metal if the process goes no further.

"In order that corrosion may proceed, the film of hydrogen must be removed. This can happen in two ways: either it may combine with oxygen in solution to form water, or it may escape as gaseous hydrogen.

"Dissolved oxygen is usually present in water solutions and removes the

A paper presented on October 7, 1941, at the Wisconsin Section Meeting, Racine, Wis., by Otto A. Halvorson, Engr., Milwaukee Water Works, Milwaukee, Wis.

* SPELLER, F. N. *Corrosion—Causes and Prevention.* McGraw-Hill, New York (2nd ed., 1935).

hydrogen film by reacting with it to form water. The process is then free to continue, that is to say, more iron can go into solution, more hydrogen can plate out, and the process can continue at a rate determined by the speed with which the oxygen removes the hydrogen. This is the second stage of the corrosion and accounts for the continuance of the process in the great majority of cases.

"In acids, the same reaction takes place. In addition to this, however, the tendency for hydrogen to plate out is much greater, and so much of it gathers on the metal surface that it is forced off in the form of hydrogen gas bubbles. Corrosion, therefore, is proportionately more rapid in acid solutions than in natural waters. Ordinarily, the iron which goes into solution is immediately thrown down as rust. After a time the rust, together with insoluble material from the water, may form a protective coating on the surface of the metal which interferes with the corrosion reactions by insulating the metal from the solution.

"Restating the foregoing theory in terms of exposed iron and steel structures, it may be said that iron in the presence of atmospheric moisture has a tendency to dissolve and then, with the help of moisture and oxygen, to change to rust. An intermediate step in the corrosion process is the formation of a film of hydrogen gas on the surface of the metal. This film, which is subsequently removed by the oxygen in the air, forms through the breakdown of the water, that is, as the iron dissolves, some of the water breaks down to form gas.

"The rate at which the hydrogen gas film forms and is removed controls the rate of corrosion. Iron dissolves faster and hydrogen gas forms faster in the presence of acids. Since industrial atmospheres contain acids, they are more corrosive than ordinary atmospheres. Conversely, under alkaline conditions, corrosion is light."

Elements of Good Coatings

With this explanation in mind, it becomes clear immediately that air, gases and moisture must be excluded from the iron or steel if corrosion is to be checked. For many years past, the practical experience of engineers and others has shown that the most efficient and economical "weather seal" is a good stable and thoroughly applied elastic coating—one that will resist fracture upon impact and yield to movement of the metal during expansion and contraction, without cracking.

In differentiating between coatings of different potentials, with respect to their behavior in the replacement series, it should be pointed out that the higher the potential the greater the activity and the shorter the life of the coating, because it continuously goes into solution thus replacing some other element coming out. In this action, the coating dissipates

itself until finally it is entirely gone. Therefore, all other conditions remaining equal, a coating of a lower potential is preferred.

Procedure and Results of Study

In the corrosion study of bolting materials and coatings, such as was made in the Construction Division of the Milwaukee Water Works, it was discovered that much could be done in the way of improving protective methods for these materials. This study does not profess to be a complete treatise on the subject of corrosion of bolting materials and coatings, but is merely a presentation of the results obtained from tests made on the materials used in Milwaukee for the fabrication of cast-iron fittings, such as gate valves, hydrants, tie-rods, etc., for the construction of underground mains.

Twenty sample bolt specimens were taken at random from stock, weighed and buried in four representative soils found within the City of Milwaukee. In June 1932, these bolts were put in quart glass jars, one bolt in each jar, containing a representative soil sample.

There were five types of bolts: mild steel, wrought iron cadmium plated, Z-metal, mild steel hot-galvanized and wrought iron. One specimen of each type was buried in clay, one in sand, one in cinders and one in muck. The soil was kept moist by periodic addition of water and all jars were kept uncovered. For purposes of comparison, all bolts were placed with the heads down. The specimens were removed in January 1939 and photographed after all loose soil had been shaken from them and again after they had been thoroughly cleaned. These photographs showed that in some cases a substantial amount of soil was cemented to the bolts by corrosion.

All soil and loose corroded material were then removed and the bolts cleaned as well as possible by careful chipping and brushing, after which they were again weighed. Where possible, the nuts were removed to see how much corrosion took place under them. Each specimen was then examined carefully and the general visible characteristics recorded as follows:

1. *Mild Steel in Clay:* Loss in weight, about 12 per cent; total free alkali, 3.06;* corrosion quite uniform; maximum pit depth, 0.02 in.; fully 50 per cent of threads corroded away; nut fits loosely; little pitting under nut; reddish brown appearance.

2. *Mild Steel in Sand:* Loss in weight, about 11 per cent; total free alkali, 3.82; corrosion quite concentrated; maximum pit depth, 0.04 in.; fully 50 per cent of threads corroded away; numerous pits 0.03 in. deep found; nut

* Throughout this description total free alkali is expressed as the number of milligrams of normal hydrochloric acid (HCl) required to neutralize the quantity of free alkali found in a 50-gram soil sample.

fits loosely; little pitting under nut; gray to black appearance with reddish brown spots.

3. *Mild Steel in Cinders:* Loss in weight, about 44 per cent; total free alkali, 2.29; corroded badly and concentrated; under strain bolt would have failed some time before; fully 90 per cent of head gone; maximum pit depth, 0.125 in.; maximum pit depth in head, 0.20 in.; nut not removed for fear of breaking specimen; thread badly corroded; reddish brown appearance.

4. *Mild Steel in Muck:* Loss in weight, about 6 per cent; total free alkali, 3.06; corrosion quite uniform; maximum pit depth on head and body, 0.035 in.; mill scale intact in spots; threads in fair condition; pits show tendency to depth rather than area; reddish brown appearance.

5. *Wrought Iron Cadmium Plated in Clay:* Loss in weight, about 3 per cent; total free alkali, 3.31; corrosion moderately uniform; maximum pit depth, 0.008 in.; grain fibers slightly visible; threaded end and head show most corrosion; mill scale intact in spots; reddish brown appearance.

6. *Wrought Iron Cadmium Plated in Sand:* Loss in weight not determined; total free alkali, 3.82; corrosion quite uniform; maximum pit depth, 0.045 in.; dark brown appearance.

7. *Wrought Iron Cadmium Plated in Cinders:* Loss in weight, about 45 per cent; total free alkali, 3.82; corroded badly, but uniformly except for ends; all mill scale gone; fibers very visible and sharp; about 50 per cent of head gone; maximum pit depth, 0.06 in.; maximum pit depth in head, 0.08 in.; reddish brown appearance.

8. *Wrought Iron Cadmium Plated in Muck:* Loss in weight, about 2 per cent; total free alkali, 4.08; corrosion moderately uniform; maximum pit depth, 0.015 in., plating quite intact; threaded end and head show most corrosion; light brown appearance.

9. *Z-Metal in Clay:* Loss in weight, about 5 per cent; total free alkali, 4.33; corrosion quite uniform; pitting more or less concentrated, head and body show most corrosion; corroded iron comes off as red powder; maximum pit depth, 0.04 in.; maximum pit depth in head, 0.08 in.; reddish brown appearance.

10. *Z-Metal in Sand:* Loss in weight, about 5 per cent; total free alkali, 3.31; corrosion quite uniform; pitting more or less concentrated; head and body show most corrosion; maximum pit depth, 0.03 in.; reddish brown appearance.

11. *Z-Metal in Cinders:* Loss in weight, about 18 per cent; total free alkali, 3.06; corroded quite badly; pitting quite concentrated with reduction of head and exposed thread; thread under nut in good condition; maximum pit depth, 0.10 in.; maximum pit depth in head, 0.17 in.; black and dark brown appearance; head appeared to have silver luster.

12. *Z-Metal in Muck:* Loss in weight, about 4.5 per cent; total free

alkali, 5.35; corrosion quite uniform; pitting more or less concentrated; head and body show most corrosion; thread shows little corrosion; maximum pit depth, 0.04 in.; maximum pit depth in head, 0.05 in.; reddish brown appearance.

13. *Mild Steel Hot-Galvanized in Clay:* Loss in weight, about 0.4 per cent; total free alkali, 1.78; corrosion negligible; corrosion spots come off in form of powder; maximum pit depth, 0.003 in.; pitting has barely penetrated coating; light gray appearance; practical value of bolt 100 per cent of original.

14. *Mild Steel Hot-Galvanized in Sand:* Loss in weight, about 0.5 per cent; total free alkali, 1.27; corrosion negligible; corrosion spots in some instances show rust, but when removed reveal zinc beneath; maximum pit depth, 0.005 in.; pitting has barely penetrated coating; light gray appearance; practical value of bolt 100 per cent of original.

15. *Mild Steel Hot-Galvanized in Cinders:* Loss in weight, about 0.6 per cent; total free alkali, 0.00; corrosion slight; corrosion spots in some instances quite large and scale off, revealing zinc beneath except where pitting has started; maximum pit depth in nut, 0.015 in.; other pits very shallow; gray appearance; greatest discoloration appeared on head and nut; practical value of bolt 100 per cent of original.

16. *Mild Steel Hot-Galvanized in Muck:* Loss in weight, about 0.6 per cent; total free alkali, 1.53; corrosion slight; coating appears thin and discloses exposed spots; coating under threads scales off quite easily in minute flakes, exposing reddish colored surface; surface has minute pits; maximum pit depth, 0.005 in.; gray appearance; practical value of bolt 100 per cent of original.

17. *Wrought Iron in Clay:* Loss in weight, about 7.5 per cent; total free alkali, 1.53; corrosion quite uniform; maximum pit depth, 0.03 in.; entire surface minutely pitted; about 75 per cent of threads corroded away; reddish appearance.

18. *Wrought Iron in Sand:* Loss in weight, about 6 per cent; total free alkali, 1.78; corrosion quite uniform; maximum pit depth, 0.05 in.; maximum pit depth in head, 0.07 in.; about 80 per cent of mill scale corroded away; some pitting in threads; fibers quite visible; nut has numerous irregular pits; reddish brown appearance.

19. *Wrought Iron in Cinders:* Loss in weight, about 5.75 per cent; total free alkali, 0.00; corrosion quite uniform; maximum pit depth, 0.05 in.; maximum pit depth in head, 0.065 in.; exposed thread badly corroded; thread under nut in good condition; dark brown appearance.

20. *Wrought Iron in Muck:* Loss in weight, about 3 per cent; total free alkali, 2.75; corrosion quite uniform; maximum pit depth, 0.05 in.; mill scale well intact; fibers visible in spots; exposed thread badly corroded; thread under nut in good condition; reddish appearance.

Weights of these bolt specimens were measured in grams. Physical properties ranged from 46,000 ultimate for wrought iron to 75,000 for Z-metal. The materials were of normal composition to S.A.E. standards with the exception of the Z-metal which is a specially heat-treated cast iron in which the iron carbide is spheroidized into a matrix of the iron. After the specimens were thoroughly cleaned, they were again photographed to picture the effect of corrosion and to provide a record for future reference. The corroded materials which adhered to each specimen were put into separate containers and turned over to a chemist for analysis.

Discussion of Results

Electrolytic corrosion can be eliminated as a possible cause of corrosion in the case of the twenty specimens used in this experiment, since stray electric currents did not come in contact with any of the containers.

From a study of the various specimens, it appears that hot-galvanized bolts will give the best results, provided they are contacted with ferrous materials. Their use with relatively larger copper and brass parts may not prove to work out so well, due to possible galvanic corrosion.

As mentioned previously the conditions were favorable for self-corrosion. The periodic addition of water to the various soils and the subsequent drying out had a tendency to add dissolved oxygen to the water. Thus, the cycle was completed; the positive iron ions were discharged into the water, hydrogen ions were deposited on the metal and, in turn, the oxygen in the water removed these. This process could go on until the entire specimen had completely corroded.

Since the corrosion varied more with the nature of the soils than the material of the bolts, it is apparent that it was caused by certain elements which were present in some of the soils and absent in the others. This naturally leads to the conclusion that galvanic corrosion was the most destructive type in this case. The greatest corrosion on each type of bolt material occurred with bolts buried in cinders. The cinders used in this experiment were a conglomeration of coal ashes which could contain any number of acids and compounds. The following table, taken from the book by C. S. Cosgrove,* gives the common ash constituents of coal:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	MgO	K_2O	Na_2C
Anthracite, %	25.66	27.03	42.83	1.56	0.17	11.83	—	—
Bituminous, %	54.80	29.20	6.80	1.40	1.00	0.60	2.10	1.90
Semi-butiminous, %	47.30	34.60	9.80	1.20	0.10	0.40	2.50	2.10
	15.20	8.60	13.30	18.10	29.60	10.00	1.80	5.30

* COSGROVE, J. J. *Coal*. Technical-Book Publishing Co., Philadelphia (1916).

In the discussion of the above results, the chemist stated that the compounds, excluding SO_2, are apt to be found in a combined neutral silicate which would be active only with the application of internal heat. The SO_2 in the presence of water, however, forms sulfurous acid which is an active corrosive agent when CO_2 is present.

The analysis of the soils in the tests, with only two exceptions, indicates an alkali condition and the greatest alkalinity occurs with those specimens that showed the greatest amount of corrosion. Since there was no analysis of the original soil, it cannot be decided definitely what took place, but it is probable that such acid as was originally present, along with the presence of carbon in the ashes, brought on electrochemical activity, as a result of which the acids broke down to form salts. This would account for the results obtained by the chemist and also the excessive corrosion in some soil samples.

Comparison of Protective Coatings

In the study of the destructive action of soils on iron and steel materials, it becomes natural to inquire about ways and means to combat the various forms of corrosion. Since only some of the more expensive alloys of steel or copper show much resistance to normal corrosion, some other method whereby the cheaper metals may be used, must be resorted to for general purposes.

Of the various metallic coatings, hot-galvanizing shows good results for what may be called a limited number of years. According to research by the National Bureau of Standards:*

"A zinc coating weighing 1 ounce per square foot of exposed surface should extend the life of the coated material at least six years in very corrosive soils and much longer under more favorable conditions."

Several other processes, among them "Parkerizing," are said to give good results. This process is used largely in the automotive industries for car bodies.

Tar-base enamels have a record of long use with good results. The manufacturer of "Bitumastic Enamel" (a coal-tar base product) indicates that that product has been used in the protection of some 16,000 ships and naval vessels and that perfect protection was provided after 25 to 30 years of service. They also cite numerous examples of the use of this material in coating gas, oil, and water pipe lines.

In his book Erick Larson† records the following information:

* Logan, K. H. and Taylor, R. H. Rates of Loss of Weight and Pitting of Ferrous and Non-Ferrous Specimens and Metallic Protective Coatings. J. Res. Natl. Bur. Standards, **12**: 119 (1934).

† Larson, Erick. Pipe Corrosion and Coatings. Am. Gas., Inc., New York (1938).

"Coal-tar enamel coatings are combinations of coal-tar pitches and binders or fillers. Their use as a corrosion-resisting cover was reported as early as 1840 by Angus Smith. Many reports of their advantages have appeared since that early date."

These enamels are of various types. The best is applied hot (300°F.) on metal heated to about the same temperature. Some, however, can be applied cold and are therefore applied in thicker coatings. Some of the advantages of coal-tar enamels are:

1. They are very easy to apply and no previous experience is required in applying them.
2. They resist physical forces that may cause damage in handling, previous to actual installation of the materials covered.
3. Temperature does not greatly affect the hardness.
4. They have a high bond value, often in excess of 900 psi. at ordinary temperatures; which, incidentally is one of the most important characteristics of a good coating material.
5. They are usually applied in thicknesses varying from $\frac{3}{64}$ to $\frac{3}{32}$ in.
6. Where they are subjected to soil stresses, they may be covered with cotton fabric or even paper.
7. Their moisture absorption is low, from 2 to 4 per cent by weight, during the first two or three years of service, after which the absorption is almost imperceptible.
8. They have a higher dielectric strength than any other widely used coating. This characteristic is of importance where electrolysis may be expected.
9. Tar-base enamels usually weigh about 100 lb. per cu.ft.
10. Though there is considerable loss, in applying them (about 10 per cent), the material being low in cost, this is a minor item.
11. They are not toxic to plant life, as a result of which roots frequently penetrate the enamel.
12. Tar-base enamels do not contain oils such as are found in asphalts; therefore, very little evaporation occurs. After years of burial they have been found to have practically the same characteristics as when first processed.
13. They will not damage or be damaged by other types of coatings.

Conclusions

From preceding data and miscellaneous information obtained from the study of various books, reports, pamphlets, etc., it is the concluding opinion that the corrosion of ferrous materials buried in soils depends largely on the characteristics of the soils. The corrosiveness of a soil can never be precisely expressed because of the variations in it, differences in

the methods of backfilling trenches, the depth of burial and the variations in moisture and temperature from year to year. Several causes appear to be responsible for the corrosiveness of soils and it is improbable that a single satisfactory method for determining soil corrosiveness can be developed.

All coatings, whether metallic, mineral or organic, tend to increase the life of the material to which they are applied. Average values sufficiently accurate to show small differences in the performance of competing materials can be secured only through the testing of a very large number of specimens. Since, in any one case, any material may prove considerably better or worse than the average, it is doubtful whether the drawing of fine distinctions between materials would be of practical value except for the consumers of very large quantities of materials. The most general conclusion is that, for best results, the material must be chosen to fit the soil in which it is to serve, since no one material is best suited for all soil conditions.

Experience in Milwaukee has led the author to believe that properly applied coal-tar enamels will give the most uniformly good and economical results as a means of combating the corrosion of iron materials in the construction of water supply systems. As for steel bolting materials, with few exceptions, hot-galvanizing has proved the most satisfactory protective measure. Other methods do not, at the present time, have sufficient evidence to substantiate their use except for experimental purposes.

Study of Solubility of Two Lead Salts in Dilute Solutions With Special Reference to the Lead Hazard in Drinking Water

By C. C. Ruchhoft and John F. Kachmar

THE application of molecularly dehydrated phosphates (pyrophosphate and polymetaphosphate) to drinking water supplies presents the question of the solubilities of lead salts in such waters. The safety of supplies in sections of the country where lead service pipes are used depends upon deposition of a protective coating inside the pipe. This coating has been studied by a number of investigators whose work has been summarized by Ingleson (1). The coating is generally considered to contain lead compounds and some iron oxide as well as organic material. Although there is no agreement on the exact composition, it has been claimed that the lead is present as a basic lead carbonate or as a solid solution of lead oxide in the carbonate. Consequently, any chemical which is capable of dissolving lead salts, such as are deposited in pipe coatings, could create a condition detrimental to the health of the water users.

Fairhall (2) has shown that 1 per cent solutions of sodium hexametaphosphate are excellent solvents for lead salts. His data (Table 1) show that, while all of these salts are relatively insoluble in pure water, their solubility is very appreciable in 1 per cent sodium hexametaphosphate solutions. The data are not directly applicable because the concentrations of metaphosphate are very much higher than would ever be used in water treatment practice. It is of interest to note that a patent has been granted for the treatment of fruit sprayed with lead arsenate based upon the solubility of lead salts in sodium hexametaphosphate solutions (3).

Hatch (4) has recently studied the effects of small doses of metaphosphate in concentrations which have been used in water treatment, in preventing corrosion of lead pipe. Using waters with pH values between 5.2 and 7.0 he found that a dose of 2 ppm. of metaphosphate decreased the concentration of lead dissolved as a result of passing the waters through lead wool. At higher pH values the lead solubility of the water decreased and there was little difference between the treated and untreated water; further, that water treated with 2 ppm. of metaphosphate showed a

A contribution by C. C. Ruchhoft, Principal Chemist, and John F. Kachmar, Assistant Chemist, U. S. Public Health Service, Cincinnati, Ohio.

considerably lower and more constant solubility of lead than untreated water. This indicates that the solvent action of metaphosphate in concentrations of a few parts per million is radically different from that at much higher concentrations. Hatch suggests that the solution-inhibiting action of metaphosphate which he observed extends to concentrations of 10 ppm. Although this work indicates that metaphosphate protects rather than corrodes metallic lead, it gives no evidence as to the possible effect on protective coatings already present in lead pipes.

Ingleson (1, p. 83) cites Muir's data on the solubility of basic lead carbon-

TABLE 1

Solubility of Various Lead Salts in Sodium Hexametaphosphate and Pure Water

SALT	SOLUBILITY IN 1% SODIUM HEXAMETAPHOSPHATE AT 25°C.	SOLUBILITY IN PURE WATER
	ppm.	*ppm.*
Lead Silicate	107	—
Lead Chromate	248	0.04
Lead Arsenate	863	0.2
Lead Sulfate	1,682	45.0
Lead Carbonate	2,150	1.7

TABLE 2

Solubility of Basic Lead Carbonate in 2,000 ppm. Salt Solutions Made in Flasks and Beakers

SOLUTION	$Pb_3(CO_3)_2(OH)_2$ DISSOLVED	
	In Flasks	In Beakers
	ppm.	*ppm.*
$(NH_4)_2SO_4$	31.1	23.2
KNO_3	38.5	23.2
$CaCl_2$	43.5	38.5
NH_4NO_3	217.5	38.5
Water saturated with CO_2	232	232

ate in 2,000 ppm. salt solutions made in beakers and flasks. These data (Table 2) indicate that most of the salts increased the solubility of basic lead carbonate in water only slightly and that only ammonium nitrate and water saturated with CO_2 raised the concentration of the lead salt to above 200 ppm.

Data on the solubility of lead salts in very dilute solutions of either the common chemicals used in water purification or of pyrophosphates and metaphosphates do not seem to have been obtained. Consequently, it was decided to make a solubility study of two common lead salts (lead sulfate and basic lead carbonate) in very dilute solutions.

Experimental Procedure

The test solutions of most of the salts were prepared by dissolving carefully weighed portions of the dry analytical reagent grade salt, when this was obtainable, in distilled water to make 1.0 per cent solutions. The metaphosphate used was the commercial product "Calgon." These solutions were then serially diluted with distilled water to prepare the dilute concentrations desired for test purposes. In the case of $Ca(OH)_2$ solution, calcium oxide was used to prepare the stock solution which was then standardized against 0.02 *N* sulfuric acid. The stock solution of $Ca(OH)_2$ was then diluted to give the desired concentrations for test in terms of $CaCO_3$. The chlorine solution was prepared with calcium hypochlorite (HTH) and was standardized against 0.025 *N* thiosulfate, after which it was diluted. The pH values of the dilute chlorine solutions were adjusted to within the range 7.0 to 8.0.

In making a test of each solute, approximately 1-gram portions of the reagent grade of the lead salt to be tested were suspended in 500-ml. portions of the prepared dilute solutions. In some of the preliminary solubility tests, two methods of accelerating the solution of the lead salts were used. In a few experiments, 500-ml. glass-stoppered bottles partially filled with the test solution containing the lead salt suspensions were shaken in a shaking machine, at room temperature, for 30 to 60 min., after which the lead was determined on the clear supernatant. In most of the early experiments, 500-ml. glass-stoppered bottles were turned end over end at 1 rpm. in a turning machine in a 20-degree constant temperature room. In a few of these experiments the dissolved lead was determined after 1, 2, 5 and 7 days in the turning machine. These experiments showed that a period of several days in this machine was required to bring the maximum amount of lead into solution.

If this procedure had been followed in all experiments, the time required to complete the tests would have been increased materially. Consequently, to complete the study in a shorter time, all of the later experiments were carried out by bringing the suspensions of lead salts in the dilute solutions to a boil, boiling for a period of 1 or 2 min., and cooling to room temperature. The cooled test solution containing the lead salt suspension was distributed into 50-ml. centrifuge tubes and swung at about 2,400 rpm. for 10 to 15 min. About 30 ml. of supernatant was then removed from each tube, care being taken not to remove any of the thin film of lead salt which, in occasional tubes, persisted in floating on the surface. The combined supernatant from each test solution was then sampled and analyzed for lead. If the separated centrifuged supernatants indicated some lead salts still in suspension, a second centrifuging was carried out.

In the preliminary experiments, after the lead suspensions had settled,

TABLE 3

Solubility of Lead Sulfate in Dilute Solutions of Various Materials

Column No.	1	2	3	4	5	6	7	8	9	10
Salt	$(NaPO_3)_6$	$(NaPO_3)_6$	$(NaPO_3)_6$	$Na_4P_2O_7$	$Al_2(SO_4)_3$	$FeSO_4$	NaCl	NH_4NO_3	$Ca(OH)_2$*	Cl_2
Medium	Distd. H_2O	Tap H_2O	Tap H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O
Procedure†	#1	#1	#2	#1	#1	#1	#1	#1	#1	#3
Concentration of Salt in ppm.	Concentration of $PbSO_4$ (as Pb) in ppm.									
0	32	28	8.0	30	31	20	33	31	29	—
1	30	22	3.9	23	31–57.2	25.2 –37	—	—	—	34.0
2	10	16	2.8	15.5	29	33 –38	—	—	—	31.0
5	3.5	20	4.7	10.8	28.5	32 –38.8	—	—	—	16.0
10	1.7	18	5.5	8.3	25.5	12 –26	34	34	30	11.0
25	4.0	3.6	6.9	3.1	22	7 –21	—	—	20	—
100	7.0	3.8	—	3.7	10.5	2.4 – 6.8	42	32	9	7.0
1000	195.	225.‡	—	66	4.5	0.08– 0.55§	75	53	370	—

* Concentration in terms of $CaCO_3$.

† Procedures: #1—boiling for 1 min. and centrifuging; #2—turning 5 days and centrifuging; #3—shaken in shaking machine for 1 hr. and centrifuged.

‡ Peptized.

§ Fe interference.

the supernatant was filtered through either No. 3 or No. 1 Whatman paper and the lead in the clear solution determined. It was found, however, that the solubility of lead sulfate in distilled water, obtained in this way, did not check with the published data. Investigation indicated that this was attributable to the adsorption of lead ions from the very dilute solutions by the filter paper during filtration. This phenomenon has been previously noted by others, whose work has been cited by Ingleson (1, pp. 29, 36). It has been claimed that lead solutions could be filtered through asbestos without loss by adsorption. The experiments described here did not bear out this observation, for filtration of standard lead nitrate solutions through an asbestos mat in a Gooch crucible also gave filtrates with reduced lead contents (85 to 90 per cent recovery).

All lead determinations were made colorimetrically with diphenylthiocarbazone according to the procedure outlined in *Standard Methods* (5), using standards containing 0, 5, 10, 15, 20, 25, 30, 40, 50 and 75 gammas of lead. Although more refined dithizone methods have been proposed, these all involve time-consuming procedures. As a whole, it is believed that the experimental procedure outlined above gave results sufficiently accurate and reliable for the purposes. If 25 to 40 ml. of a sample failed to give a perceptible color due to lead, 50 to 100 ml. of the sample were concentrated to 10 to 15 ml. for the determination.

Discussion of Results

In Table 3 are presented the analytical data obtained for the solubility of lead sulfate in dilute solutions of seven salts and chlorine. Data for similar tests of basic lead carbonate ($Pb(OH)_2 \cdot 2PbCO_3$) in the same concentrations of these solutions are given in Table 4. Two series of tests with each lead salt were run with Cincinnati tap water solutions of metaphosphate. All of the remaining series of experiments were made with distilled water solutions.

With every series of salt solutions, as a check on the work, the solubility of the lead salts was determined in distilled water or tap water (i.e. at zero salt concentration). As is shown in Table 3, the seven values obtained for the solubility of $PbSO_4$ in distilled water are 32, 30, 31, 20, 33, 31 and 29 ppm. or a mean of 29.4 ppm. of lead. This is equivalent to 43 ppm. of $PbSO_4$, a result agreeing very well with the value in Fairhall's table. These data show that a fairly accurate and reproducible value for the solubility of lead sulfate in distilled water was obtained by the procedures followed. Similarly, in Table 4, seven values for the solubility of basic lead carbonate in distilled water ranging from 0.21 to 0.81, with an average of 0.41 ppm. as lead, were obtained. This indicates that the precision of the data for the basic lead carbonate is lower than for the lead sulfate.

TABLE 4

Solubility of Basic Lead Carbonate in Dilute Solutions of Various Materials

Column No.	1	2	3	4	5	6	7	8	9	10
Salt	$(NaPO_3)_6$	$(NaPO_3)_6$	$(NaPO_3)_6$	$Na_4P_2O_7$	$Al_2(SO_4)_3$	$FeSO_4$	NaCl	NH_4NO_3	$Ca(OH)_2$*	Cl_2
Medium	Distd. H_2O	Tap H_2O	Tap H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O	Distd. H_2O
Procedure†	#1	#1	#2	#1	#1	#1	#1	#1	#1	#3
Concentration of Salt in ppm.	Concentration of $Pb(OH)_2 \cdot (PbCO_3)_2$ (as Pb) in ppm.									
0	0.35	—	0.41	0.21	0.24– 0.4	0.32	0.81	0.52	0.4	—
1	0.15	0.18	0.21	0.24	0.26– 0.5	0.2 – 1.0	—	—	—	0.43
2	0.95	0.19	0.17	0.18	0.3 – 2.0	0.2 – 2.0	—	—	—	0.55
5	0.18	0.29	0.15	—	0.4 – 3.2	1.2 – 1.7	—	—	—	0.62
10	0.47	0.67	0.25	0.15	1.3 – 19	7.4 –12	0.63	2.5	0.4	0.46
25	5.0	0.17	0.75	7.8	17 – 43	23 –26	—	—	0.4	—
100	36.0	0.94	1.70	79.	50	25 –49	0.53	18.3	33.	0.89
1000	208.	131.	—	600.	10 –100	1.1 – 4	1.0	88	500.	—

* Concentration in terms of $CaCO_3$.

† Procedures: #1—boiling for 1 min. and centrifuging; #2—turning for 7 days and centrifuging; #3—shaken in shaking machine for 1 hr. and centrifuged.

Because the authors were interested primarily in the order of magnitude of the lead dissolved by the solutions, however, these results were considered satisfactory.

The first column in Table 3 shows that the solubility of lead sulfate decreased in distilled water as the concentration of metaphosphate was increased from 0 to 10 ppm. As the metaphosphate concentration was increased from 10 to 100 ppm., the soluble lead found also increased, but still remained below the value found in distilled water alone. At 1,000 ppm. of metaphosphate, the lead value increased to 195 ppm. The solubility data for lead sulfate in Cincinnati tap water solutions of metaphosphate (Columns 2 and 3, Table 3) confirm the data of Column 1 with respect to the repression of the solubility of lead sulfate in low concentrations of metaphosphate.

Column 4, Table 3, shows that small concentrations of sodium pyrophosphate also decreased the solubility of lead sulfate in distilled water. Minimum lead solubilities were obtained in the presence of 25 to 100 ppm. of this salt. In 1,000 ppm. of pyrophosphate the lead solubility was about double that in distilled water.

Four separate solubility experiments were carried out with the aluminum sulfate and ferrous sulfate solutions. In Columns 5 and 6 of Table 3, the data showing the range of dissolved lead found are given. Concentrations of alum up to 25 ppm. show little effect on the lead sulfate solubility. As the concentration of alum increased above 25 ppm., the effect of the common ion ($SO_4^=$) becomes apparent and, as would be expected from the law of mass action, the solubility of the lead salt is decreased. With ferrous sulfate the results were similar to those for alum except that the effect of the common ion becomes evident somewhat sooner at concentrations of about 10 ppm. In the lower concentrations of sodium chloride, ammonium nitrate and calcium hydroxide examined, practically the same solubility of lead sulfate was obtained as for distilled water. When the salt concentrations reached 1,000 ppm., sodium chloride and ammonium nitrate increased the lead solubility slightly, but the calcium hydroxide yielded 370 ppm. of soluble lead, which was the maximum obtained in this series of experiments. Free chlorine in distilled water also decreased the solubility of the lead salt as shown in Column 10, Table 3.

Because of the lower solubility of basic lead carbonate most of the data in Table 4 were obtained only after concentrating the samples. Low concentrations of metaphosphate (1 to 10 ppm.) are again shown to decrease the lead solubility slightly (Columns 1, 2 and 3, Table 4). With concentrations of 25 ppm. or more of metaphosphate the lead solubility was increased considerably and reached 208 ppm. of lead with 1,000 ppm. of metaphosphate. Practically the same phenomenon was observed with

pyrophosphate. With 1,000 ppm. of pyrophosphate, 600 ppm. of lead were found, indicating that the pyrophosphate, at this highest concentration, was the most effective of all the salts tried for dissolving basic lead carbonate.

The results with aluminum sulfate solutions with basic lead carbonate indicated a slight increase in lead solubility with increasing concentrations of $Al_2(SO_4)_3$. As with $PbSO_4$, a series of four separate determinations was made. The individual determinations for any concentration of $Al_2(SO_4)_3$ did not check exactly, but were of much the same order of magnitude. It was noticed that the individual alum solutions varied in pH, and there was evidence that those with lower pH values had the greater solvent action on the carbonate.

With 10 ppm. or more of alum the solubility of the basic lead carbonate is increased considerably. There was no effect on lead solubility up to about 5 ppm. of ferrous sulfate. Definite increases in the lead salt solubility, however, were obtained with concentrations of ferrous sulfate of 5 ppm. or more. Maximum concentrations of 23 to 49 ppm. of lead were found in solutions of 25 to 100 ppm. of ferrous sulfate. Sodium chloride had little effect on the solubility of this lead salt at any of the concentrations tried. Ammonium nitrate, in concentrations of 10 ppm. or more, increased the solubility of basic lead carbonate considerably. Calcium hydroxide had no effect in concentrations up to 25 ppm., but a tremendous effect was noted at concentrations of and above 100 ppm.

The results of the basic lead carbonate solubility tests in dilute chlorine solutions were not very striking, but from these it may be concluded that there is no danger of increased lead content in water treated with the doses of chlorine ordinarily used in practice.

Summary

In this study the solvent action, on basic lead carbonate and lead sulfate, of dilute solutions of chlorine, sodium chloride, ammonium nitrate, calcium hydroxide, alum, ferrous sulfate, sodium hexametaphosphate and pyrophosphate was investigated. These materials, with the exception of sodium chloride and ammonium nitrate, are commonly used in water treatment plants. Even the two excepted materials can be expected to be found present in small quantities in water supplies. The experimental results obtained are an indication as to the extent to which the above materials, in concentrations most often encountered, may be expected to dissolve or erode the protective coating in lead pipes, and thus give rise to a health hazard. The data do not give any information as to the solvent action of the above materials on metallic lead itself.

Of these materials, sodium chloride and ammonium nitrate at concen-

trations of 100 ppm. exhibited the same degree of solvent action as distilled water. Little change in the quantity of lead dissolved was observed with calcium hydroxide solutions in concentrations of 1 to 25 ppm.; at concentrations of 1,000 ppm. $Ca(OH)_2$ (as $CaCO_3$), however, very considerable quantities of the lead salts were dissolved. The alum and ferrous sulfate solutions in concentrations of 1 to 5 ppm. also showed no augmented solvent action over that of distilled water. With higher concentrations of these salts, the solubility of lead sulfate decreased, possibly because of the effect of the common ion; the solubility of basic lead carbonate, on the other hand, was increased appreciably. Chlorine solutions in concentrations of 1 to 100 ppm. repressed the solubility of lead sulfate slightly and had no apparent effect on the solubility of the basic lead carbonate.

Concentrations of metaphosphate and pyrophosphate in the range of 1 to 10 ppm. decreased the solubility of both lead salts in comparison with their solubility in distilled water. At least a concentration of 25 ppm. of these phosphates is required before the lead dissolved is approximately the same as that dissolved by distilled water; with lead sulfate about 100 ppm. of the salts are required. It is only when concentrations near 1,000 ppm. were used that the metaphosphate and pyrophosphate exhibited a very strong solvent action on the two lead salts. Therefore, the addition of metaphosphates to water supplies, in the concentrations used in practice, apparently represses the solvent action of water on lead salts. Thus, on the basis of experimental data hereinbefore presented, no health hazard is to be expected from the use of water treated with metaphosphate and delivered in lead pipes as a result of possible solvent action of the metaphosphate on the protective lead oxide-carbonate coatings formed in the pipes. Hatch (4) has already shown that there is no danger from any solvent action on metallic lead itself.

In conclusion it may be pointed out that large residuals of ferrous or aluminum sulfate in treatment practice might add to the hazard where lead services are used.

References

1. Ingleson, H. *The Action of Water on Lead With Special Reference to the Supply of Drinking Water.* Water Pollution Research Technical Paper No. 4, H.M.S. Office, London (1934).
2. Fairhall, L. T. Communication to J. K. Hoskins (June 1941).
3. Hall, R. E. Treatment of Fruit. U. S. Pat. 2,082,573 (June 1937).
4. Hatch, G. B. Inhibition of Lead Corrosion With Sodium Hexametaphosphate. Jour. A.W.W.A., **33:** 1179 (1941).
5. *Standard Methods of Water Analysis.* Am. Public Health Assn. and Am. Water Works Assn., New York (8th ed., 1936).

Accelerated Tests for Determination of Attrition Loss of Carbonaceous Zeolites

By S. J. Broderick and E. S. Hertzog

AN ACCELERATED method for determining "attrition loss" of zeolites is given in the tentative specifications being developed by the A.W.W.A. Committee on Specifications for, and Methods of Testing, Zeolites. The test was designed primarily for the greensand glauconites and synthetic zeolites and is less satisfactory when used on the carbonaceous zeolites. The test is based on measuring the turbidity of a water mixture, the turbidity being produced by agitating mildly a definite quantity of zeolite with water on a wheel rotating at a speed of about 17 rpm. and measured with the Jackson turbidimeter. Some laboratories have suggested that the method of determining attrition loss should be based on screening the attrition fines and weighing the various fractions. Moreover, there is a possibility that a type of agitation more drastic than the rotating wheel would be better suited to carbonaceous zeolites.

Carbonaceous zeolite, a new water-softening material, has physical properties decidedly different from those of the other zeolites, thus it does not appear that a test which would be wholly satisfactory for some of the other water softeners would be readily adapted to this product. Consequently, this investigation was undertaken to collect quantitative data on various artificial methods of producing attrition of carbonaceous zeolites. The results may be of value to the industry as a guide in developing a satisfactory testing procedure.

Apparatus and Screening Technic

Regenerated zeolite was employed in determining attrition loss. If spent zeolite is used, the degree of exhaustion might vary, and, in some instances, the kind of cations saturating the zeolite might influence the attrition loss.

A contribution by S. J. Broderick, Assoc. Physical Chemist, and E. S. Hertzog, Assoc. Chemist, Nonmetals Div., Bureau of Mines, Southern Expt. Station, Tuscaloosa, Ala. Published by permission of the Director, Bureau of Mines, U. S. Dept. of Interior.

The samples of zeolite available in the laboratory were spent zeolite taken from the exchange testing column after determination of exchange capacity. The spent zeolites were kept under water in stoppered bottles until needed for the attrition tests, when they were regenerated. The air-dry weights of the available spent samples ranged from 75 to 100 g. and all samples had been roughly screened through 28-mesh on 35-mesh on the Tyler screens.

To regenerate the zeolite the excess water was drained from the stored bottles and the spent samples were treated with 315 ml. of 0.5 *N* HCl. The zeolite and acid were stirred frequently for 20 min., then the zeolite was filtered and washed twice with distilled water. After draining, the filter paper and zeolite were spread on a large watch glass and allowed to air-dry at least 2 days at room temperature.

The entire air-dried sample was rolled on a mixing cloth, quartered, and a sample of properly mixed material was taken from alternate quarters to be reserved for the attrition test. This sample of 45 to 50 g. was hand-screened on 6-inch-diameter 28- and 35-mesh sieves. In screening it is essential that removal of minus 35-mesh material be complete. To prevent overloading of the screens, the material was screened in two batches with not over 25 g. to each screening. The screening time for each batch was 5 min.

Care must be taken to develop a uniform screening technic and to adhere to it. For the attrition test the 28- to 35-mesh fraction was used. The fraction remaining on the 35-mesh sieve was emptied and the sieve given a light tap with the hand while in the inverted position. Many grains of zeolites were imbedded in the sieve, and those were discarded as not suitable for testing.

The 28- to 35-mesh fraction was placed in an airtight glass sample bottle and labeled "stock attribiton sample." Five grams of the stock sample is taken for each attrition test. Before each test the entire stock sample was emptied out of the bottle and rolled on a sheet of paper to overcome any tendency of the grain to segregate; then, by means of a spatula, a 5-gram attrition sample was taken from the flattened pile. Meticulous care was exercised to obtain a representative sample. The fact that the sample was closely sized helped considerably. The stock sample was then mixed, and a duplicate sample was taken for use as a blank to represent zero attrition.

The samples were placed in wide-mouth screw-capped bottles 2 in. in diameter by $4\frac{1}{4}$ in. high; then 50 ml. of distilled water was added to each bottle, and the caps replaced. One bottle was placed in the reciprocating machine (Fig. 1) for 4 hr. of agitation, whereas the blank sample remained on the bench without agitation for the same length of time. The recipro-

cating machine was operated at a speed of 162 rpm. and had a stroke of $3\frac{3}{32}$ in. The action of the machine kept the liquid and sample in a violent state of agitation so that the particles rubbed against each other constantly, with attendant abrasive action. Drive was by a motor of $\frac{1}{3}$ hp. capacity, running at a speed of 1,725 rpm. The speed was reduced by a gear reductor having a ratio of 10:1.

After one sample had been agitated with water for 4 hr. and the other left in quiet contact with water for the same period, both samples were wet-screened and filtered by washing the contents of the attrition bottle onto a nest of 100- and 200-mesh sieves, 3 in. in diameter. The 100-mesh sieve always retained at least 95 per cent of the sample, which was then washed with a stream of water only enough to cause all minus 200-mesh material to pass the 100-mesh sieve. It was not necessary to wash all minus 100-mesh material through the 100-mesh sieve because later the

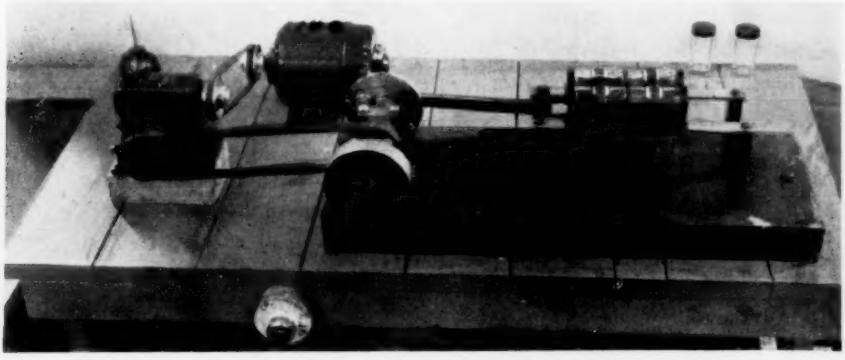

FIG. 1. Reciprocating Machine for Attrition Testing

dried sample was rescreened. Next the upper sieve containing most of the sample was removed, and the small quantity of plus 200-mesh material was washed on the 200-mesh sieve with a fine jet of water. This washing assured an accurate wet screening on the 200-mesh sieve without much effort. The material on the sieves was then transferred to a filter, drained, and air-dried at room temperature.

The liquid passing the 200-mesh sieve was caught in a beaker and diluted to 200 ml. in a volumetric flask. The turbidity was then determined by means of the Jackson candle turbidimeter shown in Fig. 2. This apparatus is equipped with a graduated tube calibrated to read in parts per million. The calibration was based on turbidity standards of powdered silica and water, hence the apparatus cannot be used to calculate the weight of suspended carbonaceous zeolite. An attempt was made to determine the actual weight of suspended matter by evaporating the filtrate to dryness and weighing the residue, but this procedure was not feasible as considerable

damp tarry matter, mixed with a trace of sulfuric acid, remained in the residue and prevented complete drying. Drying for several hours at 110°C. *in vacuo* failed to produce a bone-dry material. If temperatures high enough to volatilize sulfuric acid are used there is no assurance that the charring will not change the weight of the colloidal zeolite. Water-soluble materials also interfere with an accurate weight determination of

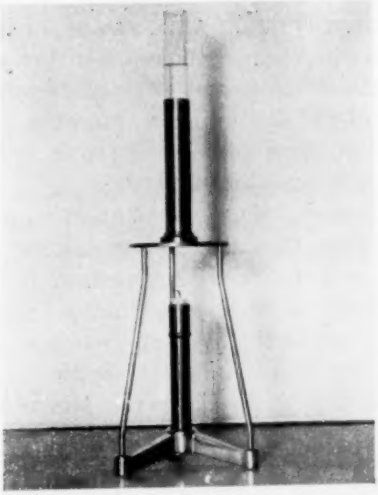

FIG. 2. Jackson Candle Turbidimeter

TABLE 1

Record of Typical Attrition Test

MESH	4 HR. ATTRITION	ATTRITION BLANK	NET WEIGHT
	g.	*g.*	*g.*
−28 + 42	4.7853	4.8446	—
−42 + 48	0.0133	0.0024	0.0109
−48 + 100	0.0145	0.0023	0.0123
−100 + 200	0.0030	0.0004	0.0026
	4.8162	4.8497	
Turbidity.....	145 ppm.	Clear	—

the suspended colloids. Everything considered, it seems preferable to use the turbidity reading in parts per million without regard to the absolute value. This turbidity reading has been found to be consistent and reliable. The turbidity test was made on material which passed 200-mesh, but most of the material was much finer than 200-mesh.

The dried sample from the attrition test was placed on a nest of 3-inch sieves (42-, 48-, and 100-mesh) and screened 5 min. by hand, the sieves

being given a rotary motion, followed by several light blows on the side with the open hand. This sequence was repeated again and again, rotating the sieve a few degrees each time. The sieves were not tapped or pounded on the table during this particular part of the test, however, as violent screening would cause more attrition. A record of a typical run is shown in Table 1.

The blank corrects for errors caused by any degradation of the zeolite due to soaking in water, abrasion while sieving, or incomplete removal of fines while preparing the original sample. In the average screen test it may be considered absurd to weight products beyond the second decimal place; the products of the attrition test, however, permit fairly accurate weighing to the fourth decimal place, owing to the special conditions under which the attrition fractions are produced.

During the early stages of the work attrition samples of 28- to 35-mesh were run on the machine, then screened on 35-mesh with the intention of using the minus 35-mesh material as a measure of the attrition. It was found, however, that the 35-mesh sieve blinded, because so much material was almost the same size as the 35-mesh sieve openings. Screening such borderline sizes with accuracy is difficult. By sieving on 42-mesh, the next smaller sieve size, blinding of the sieves was minimized.

Calculation of Attrition Values

The proper interpretation of the attrition data is not simple and may be open to question. For example, the weight of the 48- to 100-mesh fraction may be taken as a measure of attrition. Again, the total weight of the three fractions, minus 42 plus 48, minus 48 plus 100, and minus 100 plus 200-mesh, could be used as the attrition value. Probably the sum of the three fractions would be a more reliable measure, but variations in the particle size would not be recognized merely by using the total weight. The authors believe that the weights of the three sizes should be used to calculate an arbitrary surface figure to be called the attrition value.

By calculating the reciprocal of the average particle size in millimeters for each size fraction, numbers representing relative surfaces per unit weight are obtained. Average particle size may be calculated in many ways, but the formulas used in this work were:

$$\text{Average particle size} = \sqrt{\frac{a^2 + b^2}{2}}$$

$$\text{Arbitrary surface of a unit weight} = \frac{1}{\sqrt{\frac{a^2 + b^2}{2}}}$$

In these equations a and b are the sizes, in millimeters, of the mean openings

of the two limiting sieves. The figures for the sizes used in the attrition test follow:

Mesh	*Arbitrary Surface*	*Surface Ratio*
−42 + 48	3.08442	1
−48 + 100	4.29074	1.391
−100 + 200	8.59328	2.786

Data given in Table 1 may be cited as an example, as follows:

Mesh	*Weight, 0.1 mg.*				*Surface Ratio*
−42 + 48	109	×	1	=	109
−48 + 100	123	×	1.391	=	171
−100 + 200	26	×	2.786	=	72
	258				352

In this case, the number 352 may be adopted as one measure of attrition. Such a number would be significant, especially when compared with similar values for other zeolites. It is really a comparison of new surface formed

TABLE 2

Attrition Tests

MESH	4 HR. ATTRITION	BLANK ATTRITION	NET WEIGHT	SURFACE RATIO	RELATIVE SURFACE
	S-1 (High Attrition Value)				
	g.	*g.*	*g.*		
−42 + 48	0.0362	0.0086	0.0276	1.	276
−48 + 100	0.0483	0.0062	0.0421	1.391	586
−100 + 200	0.0106	0.0018	0.0088	2.786	245
					1,107
−200 turbidity	265 ppm.	Clear			
	S-12 (Medium Attrition Value)				
−42 + 48	0.0112	0.0048	0.0064	1.	64
−48 + 100	0.0172	0.0058	0.0114	1.391	159
−100 + 200	0.0060	0.0018	0.0042	2.786	117
					340
−200 turbidity	190 ppm.	Clear	190 ppm.		
	S-16 (Low Attrition Value)				
−42 + 48	0.0022	0.0015	0.0007	1.	7
−48 + 100	0.0018	0.0008	0.0010	1.391	14
−100 + 200	0.0014	0.0004	0.0010	2.786	28
					49
−200 turbidity	140 ppm.	Clear	140 ppm.		

in the 42- to 200-mesh size range. Table 2 gives detailed results on three samples representative of high, medium, and low attrition values.

Effects of Certain Variables

Fresh, Spent, and Regenerated Zeolites

The testing of freshly activated, unused zeolites was not considered advisable, as such material is activated by various processes in which different highly concentrated reagents are used and which may contain some residual chemical that has not been completely removed by washing. Even if

TABLE 3

Comparison of Regenerated and Spent Zeolite

CONDITION	MESH	SURFACE RATIO	SAMPLES							
			S-6		S-11		S-12		S-13	
			Net Weight	Relative Surface	Net Weight	Relative Surface	Net Weight	Relative Surface	Net Weight	Relative Surface
			g.		*g.*		*g.*		*g.*	
Regenerated	−42 + 48	1.	0.0042	42	0.0033	33	0.0064	64	0.0112	112
	−48 + 100	1.391	0.0062	86	0.0048	67	0.0114	159	0.0176	245
	−100 + 200	2.786	0.0025	70	0.0006	17	0.0042	117	0.0046	128
				198		117		340		485
	Turbidity, *ppm.*		230		110		190		155	
Spent	−42 + 48	1.	0.0046	46	0.0040	40	0.0094	94	0.0114	114
	−48 + 100	1.391	0.0060	83	0.0043	60	0.0146	203	0.0183	255
	−100 + 200	2.786	0.0016	45	0.0010	28	0.0042	117	0.0051	142
				174		128		414		511
	Turbidity, *ppm.*		210		90		150		140	

washing has been very complete, other factors remain that affect the surface. It is known that freshly activated zeolites cannot be tested for exchange value successfully until they have been spent and regenerated at least once. The preliminary reaction with hard water and the subsequent regeneration displaces and removes certain cations which affect the normal water-softening process. This indicates clearly the possibility of variations in the surface condition of fresh zeolites during the first cycle of a softening run. It appears, therefore, that the fresh zeolite would be in the least desirable condition for testing.

Table 3 compares the results of a few tests made on spent zeolites with

results on the same material after regeneration. The fact that the turbidity of the regenerated material was definitely higher than that of the spent zeolite probably indicates a slight swelling or softening of the zeolites by the regenerating acid. The sizing analysis did not show so pronounced a trend, although three of the four samples were somewhat less friable after regeneration.

The A.W.W.A. Committee on Specifications for, and Methods of Testing, Zeolites has in its tentative reports recommended the use of regenerated material for the attrition test. The spent material, especially that taken from commercial filters in widely separated sections of the country, would not be in comparable states of exhaustion. It would contain ad-

TABLE 4

Effect of Variation in Attrition Time

SAMPLE	MESH	RELATIVE SURFACE PER HOURS OF ATTRITION					
		0	1	2	4	8	16
A	−42 + 48	16	40	52	92	156	213
	−48 + 100	18	74	108	171	278	415
	−100 + 200	11	56	89	120	167	223
		45	170	249	383	601	851
	−200 Turbidity, *ppm.*	Clear	80	130	200	270	410
B	−42 + 48	34	98	115	157	220	318
	−48 + 100	53	142	174	230	332	502
	−100 + 200	22	78	134	189	262	384
		109	318	423	576	814	1,204
	−200 Turbidity, *ppm.*	Clear	140	180	240	320	450

sorbed elements, such as calcium, magnesium and iron, in proportions depending on the composition of the waters treated and the requirements of the particular plant. On the other hand, the zeolites lose such adsorbed cations during regeneration and approach a common surface condition in which they can more properly be compared.

Varying Time of Attrition

Two series of tests were made to determine the effect of varying the time of attrition. The procedure was the same as that used in the regular tests except that six tests were run on each sample, one each at 0, 1, 2, 4, 8, and 16 hr. Results (Table 4), as would be expected, showed that the amount of material in each size fraction (below 42-mesh) and the turbidity

increased with increasing time of attrition. On the other hand, the amount of fines produced per hour decreased as the period of attrition was extended. A brief tabulation based on the turbidity values for Sample B (Table 4) illustrates these facts:

Attrition, hr.	*0*	*1*	*2*	*4*	*8*	*16*
Turbidity, *ppm.*	Clear	140	180	240	320	450
Turbidity increase, *ppm.*	0	140	40	60	80	130
Increase per hr., *ppm.*	0	140	40	30	20	16.3

In this tabulation the increase per hour is for the interval of time between two adjacent runs. For example, the interval between the 4- and 8-hour runs would be based on a 4-hour interval. Similar tabulations on the screen-sized material would show a like trend, indicating that the material comprising the outer coatings of the zeolites is the softest and most friable.

Influence of Method of Activation Upon Attrition Values

A series of experimental zeolites made from the same sample of coal exhibited as wide a range of attrition values as did the exchange values of zeolites made from different coals. Table 5 gives data on zeolites made from the same stock sample of Brilliant coal. These zeolites were made by sulfonating the coal with gaseous sulfur trioxide in a revolving drum at the temperatures given. The data show that the activation process can greatly change turbidity, attrition, and exchange values, and that the three variables are more or less independent. If all of the zeolites are made from the same coal, high turbidity will generally be associated with high attrition value.

Results

Attrition Tests on 16 Carbonaceous Zeolites

Samples of 16 coals were obtained from the Coal Division of the Bureau of Mines, Pittsburgh, Pa., on which complete chemical and petrographic analyses had been made. These samples had been classified into three types—bright, splint, and cannel coals.

The primary object of the research on these coals was to discover the relationship between exchange capacity and any physical or chemical properties of the coals. A complete discussion of the methods of activation, apparatus used, laboratory technic, and exchange values has been given in a paper by Broderick and Bogard.* Table 6 gives the attrition data obtained on the 16 sulfonated coals prepared by them and includes the exchange capacities of those samples. The zeolites reported in Table 6

* Broderick, S. J. and Bogard, A. D. Carbonaceous Zeolites From Coal. Ind. Eng. Chem. **33:** 1291 (1941).

were all activated by the same method, in which dry sulfur trioxide was passed over 28- to 35-mesh coal contained in a rotating steel drum at a temperature of 150°C. until the coal seemed to be saturated. The material was then removed from the drum, washed thoroughly to remove excess

TABLE 5

Type of Activation Changes Attrition Values

TEST NO.	TURBIDITY	ATTRITION VALUE	TIME OF ACTIVATION	COAL SATURATED WITH SO_3	ACTIVATION TEMPERATURES	EXCHANGE VALUE
	ppm.		*hr.*		*°C.*	
15-2	80	275	5	No	140–150	700
15-3	167	434	5	No*	175–200	6,420
15-4	380	4,006	5	No	175–200	7,475
15-5	535	3,368	5	No	210	6,430
15-6	415	3,818	$8\frac{1}{2}$	Yes	175	11,250
15-7	165	1,750	$7\frac{3}{4}$	Yes	100	8,450

* This sample was activated with moist gas; all others were activated with dry gas.

TABLE 6

Attrition Data on 16 Carbonaceous Zeolites

BRIGHT						SPLINT					
Sample	Bed	Attrition value	Turbidity	Fuel ratio, $\frac{FC}{VM}$	Exchange value	Sample	Bed	Attrition value	Turbidity	Fuel ratio, $\frac{FC}{VM}$	Exchange value
S-2	High Splint	629	68	1.18	9,800	S-1	High Splint	1,107	265	1.62	10,700
S-4	Millers Creek	457	122	1.57	9,950	S-3	Millers Creek	318	255	1.36	10,950
S-9	Alma	352	145	1.52	10,800	S-10	Alma	197	175	1.46	12,800
S-14	Powellton	242	145	1.86	10,850	S-15	Powellton	484	455	1.88	10,850
S-8	Clintwood	208	120	1.91	12,025	S-7	Clintwood	500	340	2.28	10,750
S-11	Dorothy	117	110	1.42	10,750	S-12	Dorothy	340	190	1.83	10,150
S-13	Pocahontas #3	485	155	4.20	11,150						
S-16	Indiana #4	49	140	1.39	12,350						
CANNEL											
S-6	No. $1\frac{1}{2}$	198	230	0.94	11,100	S-5	Straight Creek	54	230	0.85	9,500

acid, and dried. Next the activated zeolite was screened on a 35-mesh sieve to remove any fines produced by the process, and the 28- to 35-mesh material was tested for water-softening capacity or exchange value. After the exchange value had been determined, the attrition and turbidity values were obtained as described earlier in this paper.

The data in Table 6 are reported in three groups, based on the types of coal. Under each classification an attempt was made to note any regularity or correspondence among attrition, turbidity and exchange values. Although these values did not correspond exactly with the chemical and physical properties of the original coals, some interesting correlations were found. Samples of both bright and splint coals were obtained from six coal beds. In these beds, the splint and bright coals occur in well-defined layers several inches thick, which may be removed in a pure state; thus, it is possible to compare these coals, which are known to be from the same bed and to have been subjected to almost identical conditions, at least after the coal was covered by the overburden. The six beds from which both bright and splint coal were obtained are listed first. The bright coals were arranged in the order of decreasing attrition values. Then the splint coals were listed in line with the bright coal from the same bed. All but one of the samples were from adjoining parts of three states—Kentucky, West Virginia, and Virginia.

Samples S-13 and S-16 were grouped separately because there were no corresponding splint coals to compare with them. In addition, Sample S-13 has a high fuel ratio which indicates a different state of metamorphism from the other coals. Sample S-16, an Indiana coal, came from a coal field widely separated from the others. The cannel coals fall in a class of their own.

Variables Controlling Attrition

The first 12 samples listed in Table 6 show that the turbidity of each splint-coal zeolite is much higher than that of the corresponding bright-coal zeolite from the same bed. In fact, the lowest turbidity of the splint material is higher than the highest turbidity of bright-coal zeolite. This trend may be explained in various ways. The splint coal may be more porous and may allow the acid to penetrate deeper, thus forming a softer layer of zeolite. It is also possible that the rougher surface of the splint material may be worn off more easily so that it forms more fines. The turbidity values of the two cannel coals which, like splint coals, have dull-surfaced particles, seem to be similar to those of splint coals.

The attrition values of the splint coals are not always higher than the attrition values of the corresponding bright coals. In fact, they may be higher or lower, depending on the fuel ratios of the original coal. Fuel ratio is the relative value of fixed carbon to volatile matter. It is a rough measure of the degree of metamorphism of the coaly material in its slow change from peat, through lignite, sub-bituminous coal, bituminous coal, semi-anthracite, to anthracite. In general, the higher the fuel ratio and the lower the content of volatile matter, the harder the coal. In bitumi-

nous coal, however, it has been found that removal of part of the volatile matter by the pressure of mountain building causes the coal to become softer, therefore, bituminous coals from the same region that have a higher volatile matter content and lower fuel ratio are harder.

Comparison of attrition values and fuel ratios given in Table 6 show that when the fuel ratio of the splint coal is greater or equal to the ratio of the corresponding bright coal, the attrition value of the splint coal is always higher. On the other hand, when the fuel ratio of the bright coal is greater, the attrition value of the bright coal is higher. This means that the hardest coal of this class may be expected to produce the hardest zeolite and exhibit the lowest attrition value. When two zeolites are made from bright and splint material of the same rank and from the same bed, the zeolite made from the splint material will be the softer.

In general, turbidity appears to represent attrition of the outer, softer coating of the zeolite and varies greatly with changes in the method of activation. Attrition value also varies greatly with differences in method of activation, but it represents breaking of the deeper and thicker layers as well as the thin outer coatings. This deeper material comes from portions less altered by the acid and therefore correlates better with the original properties of the coal.

Correlation of attrition and turbidity values with the chemical and physical properties of coal is difficult on account of the great influence of method of activation. It was only because all 16 samples were activated at the same temperature and by the same method and were saturated with SO_3 to an approximately equal degree that any correlation of the attrition values with properties of the original raw material was possible.

Summary

An accelerated laboratory attrition test has been developed to evaluate comparative service characteristics of carbonaceous zeolites. The test is based on agitating weighed quantities of the zeolites vigorously in water for a definite length of time. A four-hour period of agitation was chosen, and at the end of this time the turbidity of the solution was determined using the Jackson turbidimeter. The turbidity is a measure of the attrition loss and indicates the durability of the zeolite in service.

Another method of determining attrition loss is to weigh the screened fractions of fine material after agitating. The weights of the screen sizes (42- to 48-, 48- to 100-, and 100- to 200-mesh on the Tyler screens) were determined, and from these, attrition values were calculated. The attrition values are calculated relative surface areas found by weighting the quantity of each fraction according to the average surface area of the particles. Formulas and examples are given for making these calculations.

Sixteen carbonaceous zeolites, made from a wide variety of coals, were studied for susceptibility to abrasion by the accelerated laboratory attrition test. Turbidity and attrition numbers were found for each coal, and an attempt was made to correlate these values with the chemical properties of the original coals. No definite relationship was found, but a marked correspondence was noted among turbidity, attrition value, and type of coal, that is, bright, splint, and cannel.

Data are given on the rate of producing attrition fines in the laboratory agitation machine over periods of 1 to 16 hr. Correspondence between turbidity and attrition values appears to be good, so either may be used as a criterion in evaluating the service characteristics of carbonaceous zeolites.

The authors are indebted to D. E. Davis, Chairman of the Zeolite Committee of the A.W.W.A., and to Howard Tiger of the Permutit Co. for their helpful suggestions during the investigation.

Rehabilitation of the Philadelphia Water Works

By Seth M. Van Loan

IN THE history of the early settlement of Philadelphia, there is mention of "great prudence and wise forethought" as regards a water supply, the early text referring to a Gneiss rock strata which lay below the surface, covered by a layer of water-bearing gravel and sand, above which a clay deposit was found. The text further points out the value of this sand and gravel as a natural filter and indicates that wells could be sunk therein to give a supply of a potable and clear water.

As the population of the city increased, the residents adopted the cesspool method of providing for local sewage, a system which destroyed the virtue of the subterranean waterways and, after 100 years, compelled the city to abandon its wells and seek its water supply from streams.

As early as 1789 the public became more or less concerned with the importance of a pure water supply. Wells were then in use as a source, but it was difficult to multiply them sufficiently to satisfy the rapidly increasing demands. Even then, in the absence of any sewerage system, they were fast becoming so polluted as to make them dangerous and epidemics were feared. Although these primitive means of drawing water served the needs of the population for more than a hundred years, one man among them had a vision of the future. Benjamin Franklin, in his will dated June 23, 1789, which left a small bequest to the city to accumulate to a large sum a century later, remarked: "Having considered that the covering of the ground plot of the city with buildings and pavements, which carry off most of the rain, and prevent its soaking into the earth, and renewing and purifying the springs, whence the water of the wells must gradually grow worse, and in time be unfit for use, as I find has happened in all old cities, I recommend that at the end of the first hundred years, if not done before, the corporation of the city employ a part of the one hundred thousand pounds [the accumulated interest of the bequest] in bringing, by pipes, the water of the Wissahickon Creek into the town, so as to supply the inhabitants." But

A paper presented on November 6, 1941, at the Four States Section Meeting, Baltimore, Md., by Seth M. Van Loan, Chief, Bureau of Water, Philadelphia, Pa.

the city's water needs could not wait until the maturity of the Franklin bequest, the money from which ultimately found its way into the Franklin Memorial Building Fund.

Construction of First Water Works

Coincident with the activity for a water supply was a general movement toward canal transportation throughout the East and particularly in Pennsylvania. The inland waterway was considered an economic and progressive movement, and among the schemes propounded was one to connect the Delaware and Schuylkill Rivers somewhat above the old city proper. There existed an old run on the Delaware River, above the present location of Vine Street, and, on the same street projected to the Schuylkill banks, there was a second run extending easterly from the Schuylkill. The thought was to connect these two runs and form a canal between the rivers, the canal to afford a means of obtaining water for the consumers and land adjacent to the banks. The method to be followed was to extend pipes from the canal banks below the water surface to supply private cisterns and public fountains. Apparently the only reason that this canal and proposed reservoir were not built was the lack of an agreement between the Delaware and Schuylkill Canal Company, in whose hands the project was placed, and the city. The citizens were then called upon to sustain the city's side of the contention, the estates of the municipal corporation were pledged for the payment of the cost of a proposed work, and not only was a loan negotiated, but its deficiency was made up by ordering a special tax. A reservoir in Centre Square, now the location of City Hall, was proposed, with plans to pump the water by steam from the Schuylkill. This formed the basis on which the first city water works was built, but the construction that followed was a modification of original plans.

A steam pump was erected in a building on the east bank of the Schuylkill River, where the present Chestnut Street crosses. Two masonry basins, one of which was connected to the river by means of tide lock gates, were built. From the second basin a subterranean tunnel was connected to a shaft or well 40 ft. deep, from which a steam pump forced the water through a 6-foot brick tunnel to the Centre Square location, where it was repumped to a tank of such elevation as to give pressure throughout the area which it was to serve. The pumping station at the Schuylkill River terminal had a capacity of $1\frac{1}{2}$ mgd. and the pump at the Centre Square, the other terminal, 1 mgd.

Meanwhile, the city had provided the distribution system. Pipe lines of wooden logs were laid, down Market or High Street and on Arch and Chestnut streets to Front. On the cross-streets were smaller mains rang-

ing from 3 to 4½ in. in bore. When on January 21, 1801, the water was first delivered through these pipes, Philadelphia could claim the finest water works in the country. The subscribers to the loan were to get free service, others were to pay a nominal charge, so it was many years before the water works became self-supporting. Despite the enthusiasm of the first year of operation, however, there were only 34 users and the revenue was $278.

Extensions and Improvements

As the city developed, the need for an increasing volume of water required the addition of three pumping stations on the Schuylkill. These three stations were later abandoned and the Schuylkill supplies then functioning were drafted at Belmont, at Queen Lane and at Shawmont. During 1851 the Kensington Station was constructed, marking the first water works to be built on the Delaware River.

During the twenty-year period that covered the construction of stations and the absorption of private works, there were complaints from the residents regarding the volume and quality of water served and suggestions for extending and improving the water supply were offered. Officials in control of the water department drew attention to the Wissahickon Creek, the Delaware and Lehigh Rivers at Easton and to the Schuylkill River above Reading; also a supply from the Perkiomen Creek was recommended, and, later, an investigation included the watershed lanes of the Schuylkill and Delaware Rivers in Pennsylvania.

Subsequent to 1900 were added new pumping stations and mains of large diameter for conveyance of water from the Delaware, which became the heavier contributor of the supply. Also a pipe distribution system was laid for fire protection throughout the congested and industrial areas of the city. This latter investment lessened the hazard of fire and reduced the draft on the filtered system of the city, as the greater volume of water for such service was pumped direct from the river.

Initiation of Treatment

Based upon the data of various studies, the recommendation of filtration of the water supply was adopted and construction, initiated in 1901, continued until 1913, when a filtered water was made available through the distribution system of the City. This construction of the filtration works, with attendant extensions and improvements, which continued through a period of twelve years, involved an expenditure of over $30,000,000 exclusive of land damages.

Upon the adoption of recommendations set forth by consulting engineers, a technical staff was organized and assigned to detail design and construc-

tion of the purification works, on which work began in 1900. Included among the structures were outstanding engineering works, largest among which were the Lardner's Point Pumping Station, the Torresdale Filter Plant and the masonry conduit slightly less than 3 mi. in length and over 100 ft. below ground surface. So similar to the rehabilitation of that period is the present effort that the parallel should not be ignored.

A reference to water mains suggests a comparison of pipe footage, which, in a way, measures the development of a city for residence and industry. Records for 1940 list 2,521 mi. of mains as against 110 in 1840, of which 46 mi. were of wood. No forecast is ventured for 100 years hence.

Recent Rehabilitation Plans

Since the inception of the Philadelphia Water Works, seven pumping stations and five reservoirs have been eliminated. Structures now existing and in service are five main and eight auxiliary pumping stations, seven reservoirs and five filter plants. Private water works, which have been acquired, include the Germantown, Chestnut Hill, Holmesburg-Tacony, Oak Lane, Somerton and Overbrook Companies, the services of all being within the boundaries of the City of Philadelphia.

Several pumping stations built and operating under steam have been redesigned and now operate under electric power. Several surveys of the distribution system to determine underground leakage have been undertaken, including one in process now (a W.P.A. project) in a congested section of the city. During the latter weeks of 1938 the Bureau of Water submitted to the Public Works Authority a program of construction to rehabilitate the existing water works. This estimate of advisable expenditures totaled about $20,000,000. Efforts to obtain needed funds from Federal sources were unsuccessful. Later, the annual revenue returns to the Bureau provided an avenue of approach to finance advisable rehabilitation of the water works. Popular vote supported a plan to negotiate a loan of $18,000,000 through a sale of bonds, and, again, consulting engineers were engaged to review the condition of existing structures and to advise methods of rehabilitation of the water system. A competent organization was enrolled and studies in detail to determine when and how an advantageous and advisable modification would apply, or where any structures should be built, were initiated. A portion of a report by a member of the consulting staff is quoted here:

"The existing purification works, judged by the standards of the period during which they were built, were well designed and constructed. The pollution of the rivers during the past 40 years, however, has increased with a growth of population and industry on the watersheds. At the same time, because of doubt as to continuance of the source of supply, improvements in

the purification system necessary to keep pace in the science of water treatment have not been made; and insufficient money has been spent for maintenance of the plants.

"The rehabilitation of the purification works includes the construction of modern type coagulation and sedimentation basins with improved chemical and mixing facilities to provide adequately for treatment of the water prior to filtration, for the construction of modern rapid sand filter plants to replace the somewhat antiquated and inefficient roughing units, for the adoption of a policy of double filtration for the entire supply, utilizing the existing slow sand filters as final or polishing units for the effluent from the rapid sand filters, for the installation of suitable equipment and treatment facilities for overcoming taste and odor difficulties when they occur, and for the installation of modern and improved chlorination equipment that can be controlled accurately.

"The improvements proposed in the system include new pumping stations, adjustment of the existing pumping facilities and installation of new equipment, construction of additional supply and distribution mains and the rearrangement of the distribution districts. Under the plan, better and more uniform pressures throughout extreme southern areas of the city will be maintained due to the storage capacity available in an existing reservoir, and the additional pipe line capacity to be provided.

"The rearrangement of the distribution districts will result in material savings in power cost due to the increased area which will be included in an interchange of districts. Many of the large commercial and industrial users are located in the involved area. Further economies will be realized in the low pressure pumping equipment which, due to storage, will not be required to meet the maximum hourly demands; and the pumps may be designed with improved operating characteristics.

"Indirect improvements will result due to the fact that a greater proportion of the supply will be taken from the Delaware River, the water of which has better physical characteristics than that of the Schuylkill and the flow of which is greater, and because of the greater flexibility of the system for the interchange of supply from one district to another during times of high demand or of operating difficulties.

"New motor-driven pumping units will be installed in two of the buildings now housing steam pumps of vertical triple expansion and turbine type. The improvements in the mains of the distribution system, in general, have been conceived to provide better service, to replace lines which have given trouble from breakage, to eliminate dead ends, to replace mains which have become too small, and to provide for extensions into newly developed territory."

Experimentation on New Techniques

Tests borings to determine foundation conditions for the various plants have been made under contract. Small scale models for experimentation on the required pre-treatment of raw water from the various sources of supply have been developed and basic data determined. Models of proposed works of correct dimensions on a 1:17 scale were constructed. A rapid mix chamber embodying an entrance channel, distributing inlets, baffles and the entire coagulation section with a distribution baffle wall between the coagulation and sedimentation sections and short training walls beyond were included.

Models of dry wells for drive of flocculators were installed for testing flows, tests being made with a dry well along the side of the coagulation basin, as might be used with transverse flocculators. This was also done with dry wells adjacent to the front of the distributing baffle for use with longitudinal flocculators.

Experiments covered: (1) the arrangement of the distribution channel, depths of water in the coagulation basin being the same as in the original models and later being divided into a lower supply channel and an upper distribution channel; (2) the distribution baffle; (3) baffling in the coagulation basin; (4) division walls in the coagulation basin; (5) placing of dry wells; and (6) use of training walls in the sedimentation section. The flocculators used in the tests were transverse type models, arranged and coupled to form two rows of paddles across the test basin. Water supply was controlled by a constant head tank, a glance at the sustained water elevation determining adjustments. Very accurate flow control was thus obtained.

Tap water was used throughout the tests. Flow was maintained 24 hr. a day, whenever possible, to avoid temperature effects or waste of time while flow was being adjusted. Testing of models as to distribution was carried out by use of dye (indigo ink), of which a saturated solution (about 1 l.) was applied in the inlet or rapid mix section. Progress of the dye front through the model was recorded on sketches of the plan, showing the horizontal distribution of flow. Vertical distribution could not be recorded in this way, as it could not be closely observed. Notes were made concerning locations of marked bottom flow. Rapidity of progress of the average dye front is evidence also of the depth of the moving front. A series of these tests was also run on models of various types of slow mixers.

Conclusions reached, which are applicable to treatment of both Delaware and Schuylkill water, were:

1. For economy in operation and to provide for all water conditions throughout the year, a 45-minute mixing period should be provided.

2. Hydraulic flow characteristics of prototypes of the various models tested would be reasonably comparable, the longitudinal shaft type producing a slightly lower dispersion index.

3. Floc formation will be assisted rather than hindered by speed increases for peripheral velocities up to 2 fps.

4. Valuable data collected relative to the ranges in specifications for the mixing mechanism for all horizontal shaft flocculators apply to paddles of both transverse and longitudinal type with baffle and port characteristics.

5. Research work is continuing to determine the values and points of application of taste-and-odor-removing chemicals.

Recommended Construction

The recommendation for construction and the anticipated completion of structures within a three-year period embrace:

1. Purification works: *Belmont*, where existing filters and basins form a part of reconstruction; *Queen Lane*, where a pre-treatment plant is to be built upon recently acquired land and where the existing mechanical filter units are to be reconstructed; and *Torresdale*, where a complete new rapid sand filter plant with appurtenant structures and equipment is to be built.

2. Pumping stations: *Belmont*, where new motor driven pumps with discharge connections to pumping mains are to be added; *Queen Lane*, where existing steam turbines are to be replaced by motor-driven units; *Torresdale*, where a new motor driven pumping station with appurtenant piping is planned; and *Lardner's Point*, where existing steam-driven vertical triple expansion pumps are to be replaced with motor-driven units and appurtenant works.

3. Auxiliary or booster stations

4. Distribution system: The addition of various steel and cast-iron pipe lines ranging from 8 to 60 in. in diameter.

Present Construction Activities

The contract activities at present include the furnishing of: pumps and motors for the Torresdale new, and the Lardner's Point existing stations; a masonry flume for Queen Lane; a 48-inch pumping main for Belmont; a 30-inch distribution main; and a substantial footage of pipe lines of lesser diameter all with related equipment. The financing of these activities involves approximately $800,000 in funds.

Difficulties are confronting the furtherance of plans and specifications due to the loss of a number of members of the technical staff, their services being sought and acquired by agencies offering a scale of pay beyond the ability of the city to meet. Also, the impossibility of normal deliveries of materials

and equipment for contractors to whom work has been awarded has created delays towards progress in the fabrication of contemplated structures.

Improvements have been designed to care for the anticipated needs of the city for a period of about 25 years. This planning, however, is based on the assumption that definite steps will be taken to reduce waste water to a recognized minimum. Upon the accomplishment of the outlined rehabilitation program, the combined weight of public opinion will be helpful and most effective if pointed toward: (1) abating the present pollution of the Delaware and Schuylkill Rivers and prevention of any addition to the wastes, both municipal and industrial, now reaching these streams; and (2) adequate appropriations in the budget for technical personnel to operate the new filter plants when built and to maintain the system.

Discussion by *Nathan B. Jacobs.* * Mr. Van Loan has given the historical background of the Philadelphia water system as it exists today and has referred to some of the problems being met in designing the improvements. Operation of the present purification works has been handicapped because of lack of proper maintenance and improved equipment, but a safe water has been furnished to the city. This fact is most interesting considering the source of supply and the opportunity for contamination.

One of the purposes of the present program of improvement is of course to provide more positive guarantees of safety, but of equal importance from the popular point of view, is the furnishing of a potable supply, free from odor and taste. Because of the presence of industrial wastes, as well as municipal sewage, in the river, this latter presents a rather difficult problem. The availability of new methods and more adequate equipment, together with experimental work now under way, however, indicates successful adaptation to the local conditions and requirements.

The program aims to accomplish much with a moderate expenditure. It includes almost complete reconstruction of the filter plants and the two major pumping stations, as well as extensive reinforcement and revision of the distribution districts. The first point decided was to continue the use of the present sources, due to the feeling, first, that the time had come when pollution of streams would be reduced instead of increased, and, second, that it was possible to obtain a satisfactory supply by the use of modern rapid sand filtration followed by slow sand filtration or polishing.

In the filtration division, the first efforts were devoted to the Torresdale Plant. This plant, having a rated capacity of 200 mgd. is the only one used by Philadelphia to treat its Delaware River supply and furnishes about half the water for the entire city. Here one of the initial problems was the

* President, Morris Knowles, Inc., Pittsburgh, Pa.

decision to be made on the question of whether to build an entirely new rapid sand filter plant or to attempt to reconstruct the existing preliminary filters into modern units. To do this, it was necessary to make preliminary drawings both for new filters and for reconstructed filters. As soon as borings were completed and the topographic survey done, location studies were made and estimates of cost prepared on the basis of the preliminary drawings. This resulted in the decision to construct new filters in a location north of the existing plant, a site which was found to be the most desirable and economical on the basis of both topography and foundations. The planning work during this period included not only the decision to build new filters and where to build them, but also determining the size of the plant—282 mgd.—the size of filter units—94 units of 3 mgd. capacity each—their arrangement, and the location and amount of plant to be allocated to the various steps in the purification process.

Another important phase of the planning at Torresdale was the study of the various conduits and units in the existing slow sand filters and pumping station to determine enough of the hydraulics of the plant to be certain that the new plant and the existing plant could be operated successfully in series. Experiments were run on a test model in the hope of developing data which would permit reducing the size and cost of the preliminary treatment plant. Work is now in progress on the design of the filter units, including the layout of the pipe galleries and the design of the preliminary treatment plant.

Location of Coagulation Basins

At the Queen Lane filtration plant, which obtains its water from the Schuylkill River, there was no question of building new filters—only that of reconstructing the existing plant. The important problem was not the filters themselves, however, but the location and design of coagulation basins and their equipment, to condition the water properly before putting it on the filters. In the preliminary studies, it was expected to construct these coagulation basins in part of the existing sedimentation reservoir. Detailed study indicated the difficulty of this construction, however, and prompted the consideration of additional property. Three sites were considered, preliminary plans made, and consideration given to the cost of these as compared to putting the coagulation basins in the existing reservoir. A contract for borings was completed and study given to overcoming foundation difficulties which were anticipated at the site. The plans and specifications for this preliminary treatment plant at Queen Lane are now practically completed.

The most urgent improvements of pumping stations were at Lardner's Point which pumps the Delaware River water filtered at Torresdale, and at

the Queen Lane raw water pumping station on the Schuylkill River. The steam-operated equipment and boilers in both plants need replacing immediately. After careful study, it was decided to use electric motors instead of steam power for the operation of these pumping stations. For the Delaware River supply this was particularly desirable because of the existence of both a gravity tunnel and a steel force main between the Torresdale Filtration Plant and Lardner's Point Pumping Station. The studies indicated the desirability of erecting a pumping station at Torresdale to supply water through the existing steel force main and the enlargement of the Lardner's Point Low Service District which was to be supplied from this new station. The enlargement of this district was prompted by the less energy required to furnish water at the lower head and the improvement to service made possible by connecting the East Park Reservoir into this system.

Meter Maintenance Practice

By A. P. Kuranz

BEFORE discussing any plans of meter maintenance, it will perhaps be best to "sell" the idea of maintaining a meter. This may seem to be a foolish point to raise, but a survey just completed in 52 cities in the United States and Canada (Jour. A.W.W.A., **33**: 1381 (1940)) indicated that some cities do not regard the meter as the precision instrument that it is. In other words, it is not, in all cases, realized that proper maintenance will more than pay for the time and money spent.

There is no standard answer to the question, "What should be a proper meter maintenance program?" because what would be good practice in one city might be poor in another. Each community has its own problem because its water supply is unique. It is realized, of course, that one water may be more corrosive or abrasive than another and that different makes of meters give different results, so what is said here about meter maintenance practice may or may not apply to any given plant. Generally speaking, however, the procedures are somewhat similar.

In discussing the problem it should be pointed out that reference is being made specifically to $\frac{5}{8}$-inch disc type meters, although, in general, the same procedures apply to all disc type meters. The goal toward which all effort is directed is to achieve as nearly 100 per cent registration as possible. Several factors will determine just how close to 100 per cent registration will be desirable. If the cost of the water sold is high, the accuracy figure should be high. If there is a problem of shortage of water, accuracy should be high. Also, if disposal of sewage is a problem, high accuracy should be the aim. Last, and most important, it should be pointed out that it is only good business practice to get high efficiency from all equipment. There seems to be no good reason why, under any circumstances, the highest possible accuracy consistent with returns involved should not be the goal.

What is meant by high accuracy, and the flows at which these accuracy tests should be made, are factors to be considered. In the matter of flows,

---

A paper presented on September 25, 1941, at the Michigan Section Meeting, Grand Rapids, Mich., by A. P. Kuranz, Supt., Water Dept., Waukesha, Wis.

for instance, many cities in the national survey, previously referred to, were still using the orifice method in describing flows. It is obvious that a $\frac{1}{32}$-inch orifice at 70 lb. pressure will permit more water to pass through it than the same size orifice at 25 lb. pressure. Adopting as a measure of rate of flow the unit "gallons per minute," which will always be a constant, it can be demonstrated that at full flow (20 gpm.) most any meter will run and register well over 90 per cent of the water passed through it. This it will do even if it has not been serviced for many years, unless, of course, it is completely stopped. At 10 gpm. most meters will do about the same as they do on full flows. At 2 gpm. (which is usually the high point in registration), the meter will register 99 to 105 or more per cent, while at $\frac{1}{4}$ gpm., it may be stopped completely or register from 0 to 102 per cent or more. A better picture of the use of water in homes is given in the following tabulation, which records the data of 2,223 hours of observation:

Rate of Flow, gpm.	*Water Used, %*
Less than $\frac{1}{4}$	9.1
$\frac{1}{4}$	4.5
$\frac{1}{2}$	1.8
1	5.0
2	11.8
4	52.4
6	14.7
10	0.7
Total	100.0

Meter Repair Practice

The importance of accuracy on low flows is clearly indicated by the fact that 13.6 of all water sold is used at a rate of $\frac{1}{4}$ gpm. or less. The accuracy of the meter in these small flows can be 95 per cent or more, depending upon the care taken in making repairs. Several steps which should be adopted in the standard practice for repairing a meter are:

1. All meters should be tested when brought into the shop, even at a low rate of flow, preferably $\frac{1}{4}$ gpm. or less.

2. No attempt should be made to clean out any deposit in the meter by placing it in the test bench backwards.

3. Complete records of these tests should be kept.

4. The meter should be carefully disassembled, and particular care should be given to the disc and chamber, since it is absolutely essential that they be properly repaired if high accuracy is to be obtained.

5. Ball sockets must be true, or, if they are badly worn, the chamber should be replaced. If balls are worn, they may be shimmed up, but the insertion of new ones is preferable.

6. The disc chamber should be carefully cleaned by using a scraper or fine abrasive material. (According to the national survey, the use of acid is fast disappearing.)

7. The gear train needs careful attention. If the oil-enclosed type is used, individual gears may be substituted, but in the open type train all gears are usually quite badly corroded.

8. The stuffing box and register, particularly the stuffing box, need careful attention so that no binding action will cause the accuracy to fall off, especially at the low flows.

9. Since most registers are now made of the heat resistive type material, it is suggested that, unless a special department is set up to repair registers, these repairs be made at the factory.

10. A test similar to that on a new meter should be conducted, and standards should be practically the same as for a new meter. Some cities require that they be exactly the same. Testing after repairing is a necessary proof of workmanship.

Savings Through Proper Maintenance

A case, which, though hypothetical, is based on facts and figures which have been developed in arriving at the cost of making repairs and the increased revenue derived from such a program, will illustrate the advantages of careful meter repairs. In a city of 100,000 population, which is 100 per cent metered, for instance, there will be approximately 22,000 $\frac{5}{8}$-inch meters. Assuming that the meters register only 50 per cent on a flow of $\frac{1}{4}$ gpm., the data of the previous tabulation would indicate that 6.8 per cent of the water passing through the meter is lost. A meter which has an accuracy of only 50 per cent on a flow of $\frac{1}{4}$ gpm. or less, however, will also have less than 100 per cent accuracy on the flows up to approximately 4 gpm. It is quite safe, then, to say that the composite registration on the meter will be only approximately 90 per cent. The average home uses about 50,000 gal. of water per year; so, if the meter is only 90 per cent accurate, payment will be received for only 45,000 gal. If the cost of water is $.20 per 1,000 gal., the loss in revenue is exactly $1.00 per year. On the basis of 100,000 population for 22,000 meters, then, the loss in revenue is $22,000 per year.

Against this saving, of course, must be applied the cost of maintenance of the meters to prevent this loss or to produce the increase in revenue. The national survey indicated that meter removals for repairs were made every $4\frac{1}{2}$ to 20 yr., the greatest number being removed somewhere between $4\frac{1}{2}$ and 7 yr. Taking 5 yr. as the average time between removals—which is being overly conservative—and 1 hr. as the average time consumed in removing a meter, repairing it and testing it (also based on the data of the

survey) the actual time required for repairs can be computed. Then, assuming labor costs of $.75 per hour, on the basis of 5 yr. between removals, the labor cost of removing, repairing, and testing would be only $.15 per meter per year. The cost of repairs varies from $.01 to $.37 per meter per year. The average cost is $.20 per meter per year. Adding the $.15 per meter per year labor cost, a total of $.35 per meter per year for labor and material is reached. No cost of overhead, housing, equipment, depreciation, etc., is included in this cost.

Since loss through defective meters was determined to be about $1.00 per meter per year with the composite registration only 90 per cent, and the cost of repairs $.35, the savings per meter per year amount to $.65. Applying that figure to a city of 100,000 population, having 22,000 $\frac{5}{8}$-inch meters, the total savings per year would be $14,300. This may be thought to be only a hypothetical case, but the figures are taken from facts established after many years of testing and cost analysis. It may be said that the value of proper, up-to-date meter maintenance practice, which includes the steps outlined and the keeping of very accurate records, will, if practiced honestly and diligently, definitely result in increased revenue and greater efficiency.

Comprehensive Survey of Large Meters in Nashville

By R. L. Lawrence Jr. and Allan R. Sharp

THE Nashville water works has been owned by the municipality for 107 years, making it one of the oldest municipally owned plants in the country. The population of the city, within the corporate limits, is 167,415, and within the metropolitan district, 241,938. Of this population, the estimated number of water consumers is 194,065. As of July 31, 1940, there were 38,813 water accounts with 38,890 meters in active service.

The total pumpage to the city for the year 1939–40 was 7,158 mil.gal., of which 5,236 mil.gal., or 73 per cent, passed through consumer's meters. The average daily pumpage for the year was 19.59 mil.gal., and the average daily consumption passing through consumer's meters was 14.347 mil.gal. The per capita (consumer population) consumption for the year was 101 gpd.

Water revenue for the year was $781,964.26, and total revenue, including permits, fees, etc., $805,307.46. Total operating cost was $297,355.77. Bond interest paid out amounted to $135,993.75, and bond retirement payments amounted to $144,000.00. The net income, which reverted to the General Fund of the city and became available for distribution to the budgets of other departments of the city, amounted to $186,045.27.

All $\frac{5}{8}$-inch meters, for consumers within corporate limits of the city, are furnished and maintained by the water works department, but are installed by the consumer at his expense. All large meters are furnished and installed by the consumer. All meters, including the $\frac{5}{8}$-inch size, to supply property outside the corporate limits, are furnished and installed by the consumer. The water works department maintains, at the consumer's expense, all meters, larger than 1 in. in size, both within and without the corporate limits.

A paper presented on October 29, 1941, at the Kentucky-Tennessee Section Meeting, Nashville, Tenn., by R. L. Lawrence Jr., Supt. and Chief Engr., and Allan R. Sharp, Sr. Asst. Engr., Nashville Water Works Dept., Nashville, Tenn.

Importance of Testing Large Meters

Water works operators, as a whole, recognize the importance of reducing or minimizing the waste of water; and most have set up a systematic program of leak elimination with a view toward reducing unaccounted-for water; but some have been prone to disregard the importance of careful periodical checks of large meters (above 1 in. in size). If a leak of very small magnitude is reported or detected, the maintenance crew is at once put to work repairing it, while, on the other hand, a large industrial meter, through which a large volume of water is consumed, might be allowed to run an under-registration of 15 to 20 per cent for a long period of time. From a standpoint of practical operation, there seems to be no difference between a leak on a main in the street and the waste of water leaking through a consumer's meter. The unaccounted-for water in Nashville has been reduced about 10 or 15 per cent in recent years, largely as a result of the intensive program of testing and repairing large meters.

Approximately 50 per cent of all meter registration in Nashville is registered on the meters above 1 in. in size. The total meter registration of all meters for the year 1939–40 was 698,000,000 cu.ft., of which amount 396,000,000 cu.ft. was large meter registration. It is apparent, then, that large meters of high accuracy are very essential to the efficient operation of a water department, particularly as the large meters usually pass large quantities of water to which the lower rate schedules apply.

Testing Program at Nashville

Previous to March 1938 no systematic periodic testing of large meters, other than repairs when registration noticeably decreased or the meters became inoperative, had been followed by the department. The Superintendent and Chief Engineer at that time outlined a procedure to be inaugurated for the testing and repairing of all large meters, placing the Senior Assistant Engineer in charge of the Meter Repair Division forces assigned to this work. The meters were to be tested in groups, beginning with the 6-inch size and continuing with the 4-, 3- and 2-inch sizes.

No testing facilities had been provided in the meter boxes to expedite the testing of the meters. Therefore, it was generally necessary to remove either the entire meter or the measuring chamber, including the piston, cylinder or chamber ring, top and bottom cylinder head plates and the meter cover, which would include the intermediate gear system and register. A measuring chamber and meter cover, from the shop supply, were installed to supply the consumer with water while the measuring chamber was being tested, installed in another meter base from the shop. In some instances, when connections were available, meters could be

tested in place. In all new meter installations, an outlet is now provided for test connections, with valves installed before and after the meter setting, so that the meter under test can be isolated from the piping of the premises supplied, while the test is being made.

The meters to be tested were for the most part of two types, rotary and piston, manufactured by two different companies. A few compound, piston, and standard current meters of other manufacturers were also included. The program did not provide for testing the fire meters, reserving that work until tests of all large size meters had been completed.

Equipment and Procedure of Testing

For making the tests, a large size portable test meter was purchased, the outfit consisting of a 3-inch short case torrent meter, with a high test aluminum case, and a $\frac{3}{4}$-inch disc type meter, both connected by quick closing valves. Meters and valves are all mounted on a skid, for ease in handling. Twelve- to twenty-foot lengths of high-pressure $2\frac{1}{2}$-inch hose are used for connecting the testing outfit to the meter to be tested. The meters have large center-hand registers reading in cubic feet. Due to the fact that no extra space was available in the Meter Repair Shop, temporary testing facilities were arranged in the machine shop at the Main Pumping Station.

The city is now constructing, as a W.P.A. project, a modern building to provide space for a Meter Repair Shop and quarters for the Repair and Maintenance Division. Ample testing space and facilities have been planned so that large as well as small meters can be tested satisfactorily.

In testing the meters at the pumping station where a large volume of water is available, a $2\frac{1}{2}$-inch fire hose is connected to a fire hydrant on the premises near the rear door of the machine shop, brought through a hole cut in the shop door and connected to the inlet side of the meter to be tested. The outlet side of the meter under test is, in turn, connected to the inlet side of the test meter, the outlet side of the test meter discharging through fire hose into a drain in the machine shop. The pressure at the pumping station fire hydrant, from which the test supply is obtained, is approximately 115 psi. By using a 2-inch reducing valve between the fire hydrant and the meter under test, however, the pressure is reduced to 65 psi. This is necessary because of the excessive water rams caused by the operation of the quick closing lever valves on the test meter.

One of the service inspectors was detailed to make the necessary arrangements with the consumers for removing and testing their meters, and to make the tests at the various rates of flow at the pumping station. A form letter, signed by the Superintendent and Chief Engineer, explaining the necessity of making periodic tests for accuracy of all water meters, and

stating that the water works department would make such necessary repairs, upon approval of the consumer, was delivered, personally, to the consumer or his agent by the Service Inspector. After proper notification of the consumer, the meter was removed and taken to the pumping station for test or, if test connections were available, was tested in place.

The meters were tested first to determine their accuracy at the time of removal. This was accomplished by checking their accuracy against the test meter, usually at five or six different rates of flow. Accuracy curves were obtained from the various meter manufacturers and the final accuracy of the meter under test was set to within plus or minus 2 per cent of the design accuracy curve as furnished by the manufacturer.

If the meter under test proves to be in such condition that it can be repaired for a reasonable percentage of its initial cost, usually not exceeding 50 per cent, the consumer is notified verbally, the repairs made, and the actual material and labor cost to the water works department, plus 10 per cent for overhead, is charged for the repairs. In many instances in the survey the cost of necessary repairs was found to be so high that it was considered advisable to recommend that the consumer replace his meter, usually with one smaller in size than that he had been using.

It might be mentioned here, too, that the survey was also used to correct the over-meterization that is so likely to occur in those water departments which do not have a minimum service charge based on the size of the meter or service pipe supplying the consumer. In many instances in Nashville, new meters, smaller in size, were installed at a cost less than the repair cost for the existing meter. In such replacements, compound meters, assuring high accuracies at all rates of flow have generally been specified.

Surveys on Over-Meterization

Interesting surveys have been made, to determine the rates of usage by consumers, who, on the basis of Billing and Assessment Division records, were thought to be over-metered. One case investigated involved an average-size hotel, supplied through a 3-inch meter, which, no doubt, generally would be considered the proper size of meter for such a service. Upon investigation with a "Meter Master," a demand meter for recording the 24-hour rate of flow through a meter, it was found that the hotel used 3,100 cu.ft. of water during the 24-hour period, the maximum usage occurring between 7:00 and 9:00 A.M. The maximum rate was only $22\frac{1}{2}$ gpm., and the 24-hour average, 16.3 gpm. This maximum rate could easily have been delivered through a $\frac{3}{4}$-inch meter. Upon the department's recommendation, the 3-inch meter was replaced with a 2-inch compound meter, thus providing ample capacity for any unusual peak load conditions

that might occur, and also providing high meter accuracy at the low rates of flow likely to be encountered.

In 1935, for experimental purposes, the department installed the first compound meter used in Nashville, to replace an obsolete 6-inch meter supplying one of the local chemical companies. The consumption through the old meter was 692,000 cu.ft. for the year previous to the change, and for the succeeding twelve months was 1,912,000 cu.ft., an increase of 1,220,000 cu.ft. in registration and $806.67 in revenue. Shortly after making this replacement, the plant superintendent, being somewhat skeptical as to the accuracy of the new meter, requested that a check test be made. Accordingly, the Water Works Department made such a test, in his presence, by coupling its test meter in series with the 4-inch compound meter supplying the plant and discharging into the company's water storage tank, thus making it possible to check both the 4-inch compound meter and the test meter against the volume of water discharged into the tank in a given time. The results showed that the test meter varied by $1\frac{1}{2}$ per cent and the consumer's meter by only $\frac{1}{2}$ per cent.

Analysis of Test Findings

Returning, then, to the question of testing and repairing meters, it should be pointed out that the department's recommendations regarding replacement of old meters are made in writing, giving full details of the tests made and the reasons for the recommendations. No time or effort is spared in making the meter tests, determining the maximum demand likely to occur, and in the careful investigation and assembling of pertinent facts, so that it will be reasonably certain that the recommendations are sound and in accordance with good water works practice. By following this policy, throughout the survey, the department has, in practically every instance, received excellent co-operation from the consumer in carrying out recommendations, to the mutual benefit of both parties.

The analysis of the test findings on one of the meter investigations, indicating the test results and operating condition of the meter as removed from service, the repairs made, the test results and operating condition obtained prior to placing the meter back in service, and the cost of repairs, will best indicate the character of the work done in the survey. Taking as representative a 4-inch piston type meter, which, in conjunction with a 3-inch rotary meter, supplies one of the major hospitals of the city, the following study was made:

Upon removing this meter for test, the accuracy was determined as follows: at 372 gpm., 93.4 per cent; at 71.8 gpm., 94.8 per cent; at 46.9 gpm., 93.9 per cent; at 17.8 gpm., 96.7 per cent; at 7.0 gpm., 91.4 per cent; and at 5.0 gpm., 87.7 per cent.

To make satisfactory repairs it was necessary to make meter part replacements comprising a new piston and shaft, a repaired register, an oil-enclosed intermediate gear train, a center shaft and driving arm, a new bridge, gear wheels, gaskets, bolts, nuts, etc., at a total materials cost of $50.00 and a labor cost of $7.15, plus a 10 per cent overhead charge of $5.72, making a total cost of $62.87.

The test results obtained after repairs and previous to placing the meter back in service were: at 209.0 gpm., 100 per cent; at 86.2 gpm., 100.4 per cent; at 45.6 gpm., 102 per cent; at 7.6 gpm., 96.9 per cent; and at 3.1 gpm., 94.9 per cent.

A study of the accuracy design curve for this particular brand of 4-inch piston type meter indicates that: at 3.0 gpm., the meter should register 96.5 per cent; at 6.0 gpm., 99.5 per cent; and at 12.0 gpm. and higher, 100 per cent. A comparison of these figures with those obtained in the final test show that, at all rates, the results check within at least 2.5 per cent of specified accuracy. On all such final tests it is attempted to obtain accuracies within plus or minus 2 per cent of those specified. According to A.W.W.A. specifications,* the standard allowable variation for 2- to 6-inch meters, within normal test flow limits, is 98 to 102 per cent, and at minimum test flow is 90 per cent accuracy.

Meter Repair Practice

In discussing meter repair practice in Nashville, remarks will be confined to the two brands of meters—one a rotary and one a piston type—previously indicated to be the predominant ones used in the 2-inch and larger sizes. Attention should be called to the fact that meter manufacturers are only too glad to make available experienced service men, from their factories, to advise and instruct water works meter repair personnel in the repair and testing of large meters. Nashville was very fortunate in obtaining the advice and suggestions of the manager of the service department of one of these manufacturers. During each of two years, this expert spent three or four days with the meter repair men who were working on the large meters and gave helpful advice and suggestions concerning the repairs that were being made. It is expected eventually to have representatives of all meter manufacturers, whose meters are on the approved list, spend some time at the department in giving this type of service.

Prior to the meter testing and repair program, the department did not attempt machining of large size meter parts in making repairs to large

* Standard Specifications for Cold Water Meters: Disc Type—Adopted by the American Water Works Association, June 9, 1921, and by the New England Water Works Association, September 14, 1921; Current Type, Compound Type and Fire Service Type—Adopted by the A.W.W.A., May 24, 1923, and by the N.E.W.W.A., March 18, 1923. Published by the A.W.W.A.

meters, replacing them instead. Since the program was initiated, however, it has been found that, in many instances, by machining pistons, cylinders and top and bottom cylinder heads, these parts can be used again at a large reduction in cost over replacement. This point, as well as others, however, will best be covered by a description of the repair procedure on the two types of meters mentioned above.

Repair Procedure for Rotary Meters

In repairing the rotary meter, the meter is first cleaned and carefully examined for wear. If, after this examination, the repair man considers the piston and chamber ring to be in such condition that they can satisfactorily be repaired and trued up for additional service, he proceeds, first checking the top of the piston with a straight edge to see if it is square and true at all points. Usually, there will be uneven wear on the top of the piston, particularly near the tips of the piston points. If the wear is uneven, the piston, which is of hard rubber, is placed in a lathe and trued up until the top is perfectly square and true—the cut taken by the lathe usually varies from 0.002 in., at the top of the piston points, where most of the wear occurs, to 0.008 in., near the center.

After dressing the top of the piston properly, the piston is scraped circumferentially by hand with a half-round file sharpened into a scraper. During the scraping, the piston is checked with a straight edge to be sure it is scraped even and true. The chamber ring, which is also of hard rubber, is then scraped circumferentially and checked with a straight edge.

Next, the top and bottom chamber ring heads, which are of brass, are placed in the lathe, and, in turn, machined to true square surfaces. A piece of heavy paper, cut to the shape of the chamber ring, of such a thickness as to give the proper clearance between the piston and chamber top head, is placed between the top of the piston and the chamber top head, the chamber ring bolted to the chamber top head, and the assembly properly placed in the lathe. The bottom of the piston and chamber ring are then machined flush, true and square, thus providing the proper clearance between the top of the piston and the chamber top head.

To be sure that the circumferential hand scraping of the piston and chamber ring has been uniform and even, the chamber ring is chalked circumferentially inside, and the piston rotated. At those points, where the chalk is not picked up by the piston, the chamber ring and piston are again checked for squareness, and scraped until the proper contact is obtained.

If the intermediate gear system is worn, it is replaced with a repaired oil-enclosed intermediate from the stock supply. Also, if the register is worn, it is replaced with a repaired register from stock.

In adjusting the accuracy of the meter by gear ratio changes, special

care is taken to stay within the allowable gear-wheel size limits for the intermediate and register gear wheels, as specified by the factory.

Repair Procedure for Piston Type Meters

In repairing a piston type meter, the same procedure of cleaning and inspection as practiced with rotary meters is followed. If, after this, the wear is such that the repair man considers it possible to make satisfactory repairs, he proceeds, first checking the clearance between the top of the piston and the top cylinder head with a standard gage developed by one of the manufacturers. This gage fits across the top of the chamber ring, with offset knife edges to the top of the piston for proper clearances. When the top and bottom of the piston are worn to such an extent that the clearance appreciably exceeds the allowable clearances, it has been general practice to discard the piston and install a new one. At present, however, an attempt is being made to machine either the top or bottom cylinder head in a lathe, until the proper clearance is obtained. The machinist's time in operating the lathe will cost from $3 to $4, whereas a new piston for a 2-inch meter costs $12; for a 3-inch, $20; for a 4-inch, $40; and for a 6-inch, $80.

The piston is then trued up by sanding (with 000 sandpaper) the top and bottom surfaces, as well as the circular piston face. The cylinder walls are sanded smooth and the top and bottom cylinder heads are both trued up, in the lathe, previous to making the cut to compensate for excessive clearance between the piston and cylinder head.

By using an oversize piston roller with the used piston, a close circumferential contact can be maintained between the outer circumference of the piston and the inner circular wall surface of the cylinder, at which point the clearance has to be kept to a minimum to prevent leakage past the piston. The oversize roller compensates for the wear on the piston shaft, the piston face and the cylinder wall.

Meter bridges, as furnished from the factory, are slightly oversize, and should be ground off on an emery wheel to give a tight fit, but should never be forced into place, as, by so doing, the cylinder walls may be forced into an eccentric shape, causing leakage past the piston and binding at certain points between the piston face and cylinder walls.

The intermediate gear systems, registers, etc., are repaired in much the same manner as previously described for the rotary meters.

Evaluation of Benefits Derived

It is recommended that any water departments or companies, which plan to inaugurate an extensive program of testing and repairing large meters, consult the meter manufacturers about the types of equipment, tools, gages, etc., best suited to the purpose.

Comparisons in registration of meters by size groups have been made, based on meter registration by twelve-month periods before and after making the tests and repairs to the meters (Table 1). Such comparisons can, of course, give but a general idea of the increase in registration resulting directly from improved meter efficiency, for it has been found that large establishments become "leak conscious" as soon as tests and repairs are made to their meters. For example, on the day that a 4-inch compound meter was installed to replace an old 6-inch meter, supplying a part of one of the railroad terminals, the terminal yard plumber found that a 4-inch yard pipe was split nearly in two and had been leaking for a considerable time. The reduction in water consumption, due to this leak, offset the additional water that would have been accounted for with the more accurate meter. The more "leak conscious" consumers become, the

TABLE 1

Increases in Revenue Resulting From Meter Repairs

SIZE	NUMBER TESTED	INCREASE IN REGISTRATION		APPROXIMATE INCREASE IN REVENUE
		In mil. cu.ft.	In mil.gal.	
6-inch	21	2.833	21.2	$1,500
4-inch	54	5.697	42.7	3,200
3-inch	36	1.662	12.5	1,100
2-inch	6	0.2344	1.76	225
Totals.....	117	10.4264	78.16	$6,025

less wastage of water will occur, and, from the standpoint of the municipal water department, the easier it becomes to attain the goal of serving a community adequately with the minimum amount of water commensurate with its needs.

The department is now testing and repairing the remainder of the 388, 2-inch meters in service. This work will, apparently, represent a much larger increase in revenue per 100 cu.ft. of registration picked up than was the case with the larger meters, because the applicable rates will be considerably higher than for the larger size meters.

On the basis of these comparisons, it is estimated that the annual increase in revenue attributable to the program will be approximately $17,000 per year, representing an estimated increase of about 189.8 mil.gal. in accounted-for water.

ABSTRACTS OF WATER WORKS LITERATURE

Key. 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31, number 3, page 481. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British); I. M.—Institute of Metals (British).*

DEFENSE

War and Infectious Disease. CLARA E. COUNCELL. Pub. Health Rpts. **56:** 547 (Mar. 21, '41). War always attended by increases in disease prevalence. Concn. and movement of large bodies of men from various parts of world, limitless hardships, with fatigue, general malnutrition, famine and exposure; lack of medical care, sanitation, and personal hygiene often experienced by civilians and soldiers alike provide fuses for explosion of widespread epidemics. Refugees and captured and returning prisoners important instruments in transmission of disease from enemy to enemy and to all civilian groups. While certain types of sickness have accompanied armies throughout centuries, nevertheless have been notable changes in prevalence and severity of wartime afflictions. History of wars before 20th Century characterized by ravages of typhus fever, smallpox, typhoid fever, dysentery, malaria, cholera, and bubonic plague. In modern warfare, influenza ("flu") and other respiratory diseases, cerebrospinal meningitis, and venereal diseases apparently of outstanding importance. While historic pestilences remain lurking dangers, controlled chiefly by unremitting application of principles of sanitation and immunology, unlikely they will again be responsible for most wartime mortality. Infections invariably killed more soldiers than did bullets until Franco-Prussian War, 1870, when German Army recorded excess of deaths from battle. In Russo-Japanese War, '04, both sides maintained higher proportion of deaths from wounds. In spite of "flu" toll, war of '14–'18 first in which U.S. fighting forces participated with fewer deaths from sickness than from battle. For entire Army, at home and abroad, however, deaths from disease pre-eminent. During and after war of '14–'18, common war diseases highly prevalent in eastern Europe. Vicious pestilence of typhus fever existed throughout Russia, Poland, and Serbia. Typhus did not spread in western Europe in these war yr. Classic infections did not constitute major sickness problems among fighting forces or civilians. "Flu" pandemic overshadowed all others and mortality from "flu" and pneumonia recalled ravages of Black Death. Cerebrospinal meningitis reached new heights. Tuberculosis and venereal disease increases caused grave concern. In U.S. Army "flu," venereal diseases, mumps, and measles most frequent causes of absence from duty. "Flu," "t.b.," measles, and cerebrospinal meningitis leading primary causes of death. Army generally had higher rates for admission and days lost from duty for infectious diseases than did forces abroad. U.S. Navy also suffered from communicable diseases, with notably higher incidence in training camps than on ship. In present war,

"flu" and cerebrospinal meningitis again showing increased incidence, both for Continent and British Isles. Typhus fever and dysentery active in eastern Europe. Typhoid fever not described as such in records of early wars but undoubtedly one of leading scourges. Apparently most fatal disease of Am. Civil War, very common in Franco-Prussian War when it spread throughout France, in Russo-Turkish War, 1877–78, and in Boer War, 1899–1902. During Spanish-Am. War, 1898, incidence rate 142 per 1,000 per yr. Large nos. soldiers contracted typhoid, diarrhea, and dysentery in Russo-Jap. War. Dysentery described by Hindus 3,000 yr. ago and was well known to early Greeks and Romans. Armies of Crusades, 13th Century, suffered greatly from it. Records indicate dysentery especially widespread during 30 Yr. War, Franco-Prussian War, and killed thousands of French and British in Crimean War, 1853–56. Diarrhea and dysentery of unusually fatal character responsible for large nos. deaths among Am. Civil War soldiers. Evacuation of school children did not result in expected increase in communicable diseases of childhood in England. For most part, health of people not seriously affected. Hazards of infection have, however, been intensified by crowding of bomb shelters. Not only "flu" and cerebrospinal meningitis but also paratyphoid fever and dysentery showed increases in '40 compared with '39. In control of disease in fighting battles, past experience can provide no rigid rules for present victory. Nevertheless, appreciation of former problems may facilitate soln. in later experience. Changed character of leading infectious disease of war, with relegation to background of scourges of past, may be considered heartening reflection of results of scientific research.—*Ralph E. Noble.*

War and Health in Britain. WILSON JAMESON. Am. J. Pub. Health. **31:** 1253 ('41). *Excerpts.*

"First of all we have experienced enormous movements of certain sections of the population from one part of the country to another. During the first 18 mo. of war, over 2¼ million mothers and children in England and Wales were transferred, under official evacuation schemes, from our big cities to smaller towns, villages and the countryside, where they were, in the main, billeted in private houses. Many of these people have been evacuated two, three, or even four times, for, as bombing became less frequent, there was a drift of evacuees back to the towns from which they came. Well over a million of these people are still in billets. It is fortunate that our housing improvements of the last 20 yr. gave us the house room to absorb this army without overcrowding, and that our householders accepted this invasion of their cherished privacy with tolerance and good will.

"In addition to the official schemes for the mass movement of selected persons, there has been, of course, a great deal of unofficial movement of people from one area to another. There has been, too, the recruitment of millions of men and women into the fighting services, many of whom have been billeted in various parts of the country. Finally great numbers of men and women have had to be taken from their homes to work in the factories that are everywhere being developed. All these comings and goings of the people have destroyed home life. No one's home is his own—he is either living in some other person's home or sharing his own with total strangers. It requires little imagination to conjure up the possible complications of such a state of affairs, and yet we have endured two years of the war without any obvious deterioration of health—and, it is hardly necessary to add, with an increasing determination to see this business through to the end.

"The plan that has been developed for transferring much of the hospital accommodation from the center of our towns to situations in the country is one that many of us would like to see a permanent feature of hospital reorganization. Some of our hospitals have been so damaged that they will have to be rebuilt. It would be folly to rebuild them on crowded and unnecessarily expensive sites.

"One of our fears was that, with the inevitable damage to water mains and

sewers by bombing attacks, there would be a great increase in the incidence of typhoid fever. Happily this fear has not been realized. In London, for instance, every type of water main has been broken in every conceivable manner. Sewers have emptied their contents into large trunk mains and polluted the water over great distances. One main, 4 ft. in diam., has been broken no fewer than eleven times, and the number of times mains have been damaged amounts to thousands. This is understandable when we recollect that the system of mains in London is over 8,000 mi. in length. The disinfection of mains under repair by means of chlorine in a strength of 10 ppm. and with a period of contact of 15 min., has, however, proved an excellent safeguard, and I am happy to say that neither has there been any outbreak of typhoid fever due to damage to mains and sewers as a result of air raids. On the other hand, we have had quite a number of epidemics of paratyphoid fever traceable in a majority of instances to infection associated with premises where bread and various kinds of pastries are made.

"The air-raid shelter problem has been one of no little difficulty. Domestic shelters and street surface shelters had been prepared against the onset of raids, but when night bombing began a year ago the public took the law into their own hands and invaded deep 'tube' stations and other underground spaces where they felt themselves to be in greater security. These places had not been prepared as dormitories, and sanitary and other arrangements were sadly lacking. . . . Reasonable shelter provision has been made for a very large mass of the people. For example, by last April the total capacity of public and domestic shelters in the county of London amounted to 2½ million persons. A census taken on April 7 showed that some 23% of the people spent the night either in public shelters or in privately provided domestic shelters—about 8% being in public shelters including the deep 'tube' stations. The rest of the people just stayed in their homes or else used shelters provided by private means. It is of interest that we have had no epidemic disease associated in particular with shelter users, nor has the incidence of vermin among such persons increased.

"After the evacuation of Dunkirk and the collapse of France in May 1940, a tremendous effort was put forth by industry. Longer and longer hours were worked, and it is interesting to record that in many factories there was actually a higher hourly output of work at the same time. This, however, could not last, and gradually output began to fall as a result of strain and fatigue. Time began to be lost through sickness and injury and workers became stale. Had the long hours continued there would undoubtedly have been a serious effect on health and efficiency. So a reduction of hours was introduced and some provision was made for holidays. It is true to say that there is little to gain and probably more to lose when the weekly hours of work exceed 60–65 for men and 55–60 for women.

"In spite of what our people have been through, I am glad to have the assurance of the Senior Medical Inspector of Factories that he finds no evidence that, in general, the health of the industrial worker has suffered materially. War conditions have, of course, resulted in the increase of certain industrial poisonings. The most noteworthy increases are associated with the processes involved in the manufacture of T.N.T. and are revealed in aniline poisoning, toxic jaundice, and in poisoning from nitrous fumes. There is, too, a higher incidence of poisoning from carbon monoxide owing to the greater use of blast and other furnaces in the making of munitions. In order to safeguard the health of factory workers, the Minister of Labor has issued an order making compulsory, when thought necessary, medical supervision and nursing and welfare services in any factory concerned with the manufacture of munitions of war."

The Determination of Arsenic in Foods Contaminated by War Gases. H. A. WILLIAMS. Analyst. (Br.) **66:** 228 ('41). Found that when usual methods for detg. arsenic applied to exam. of foodstuffs contamd. by war gases, results

extremely unreliable; recovery of arsenic usually between 30 and 50%. In method found most suitable, sample of foodstuff (1.4 g. convenient wt.) digested with 10 g. potassium sulfate, 2 ml. of 10% soln. of copper sulfate, and 20 ml. of concd. sulfuric acid. If sample contains high proportion of fat, may be necessary to add further 5–10 ml. of sulfuric acid during digestion. When liquid clear, dild. with about 70 ml. water and boiled for 2–3 min. to expel sulfur dioxide; then cooled and dild. to 100 ml. with distd. water. Aliquot portions of soln. taken for Gutzeit tests, and dild. to 50 ml. with soln. contg. 10% potassium sulfate, 0.2% copper sulfate, and 10% sulfuric acid. After addn. of 0.5 ml. of stannous chloride, Gutzeit test carried out in accordance with B.P. technique except that ¼" pad of asbestos packed under lead paper to prevent spray of acid being carried through. Stains compared with stds.—*W.P.R.*

The Rapid Determination of Arsenic in Foodstuffs Contaminated With Lewisite. W. J. Stainsby and A. M. Taylor. Analyst. (Br.) **66:** 233 ('41). Rapid method for detn. of arsenic in foodstuffs contamd. by lewisite, but not by other arsenical gases, described. Foodstuff boiled with strong aq. soln. of alkali to break down food material and to hydrolyze liberated lewisite. Then acidified with stannated hydrochloric acid, and potassium iodide added to reduce any quinquevalent arsenic to trivalent form. After reduction of arsenious acid to arsenic by means of zinc, normal Gutzeit procedure used. Comparative detns. made by this method and by modification of wet oxidation-distn. procedure in which arsenic trichloride distd. into ice-cold distd. water instead of into nitric acid. In general, results of two methods agreed but with certain foods anomalous results obtained.—*W.P.R.*

Determination of T.N.T. (2,4,6-trinitrotoluene) in Air. K. Kay. Can. J. Res. **19:** B: 86 ('41). Describes method developed by Indus. Hygiene Lab. of Can. Dept. of Pensions and Natl. Health, Ottawa, for detn. of 2,4,6-trinitrotoluene in air of factories. Method depends on red color produced when soln. of T.N.T. in acetone treated with soln. of sodium hydroxide in water. Air to be tested bubbled through acetone at rate of 0.5 l. per min. for period of about 1 hr. In carrying out test, 0.1 ml. of 20% soln. by wt. of sodium hydroxide in water placed in 1.5-ml. test tube; 1 ml. of soln. of T.N.T. in acetone added and tube inverted several times before being allowed to stand. Red color develops at partition of two phases and migrates into acetone phase. Color compared with that obtained from std. solns. At room temp. color develops within 10 min. and stable for 30 min., after which it gradually fades. Measurable color developed by solns. contg. as little as 0.000004 g. T.N.T. per ml. Possible to differentiate with naked eye, color produced in test solns. varying in concn. by ±10% over range 0.000004 g. to 0.00004 g. per ml.—*W.P.R.*

A New Apparatus for the Detection of Mustard Gas. F. C. Hymas. Chem. & Industr. **59:** 779 ('40). Apparatus for detection of mustard gas consists of a carbon dioxide generator contg. mixture of sodium bicarbonate and tartaric acid onto which stream of water can be admitted from tap funnel. Suspected material placed on plug of cotton wool in second funnel, to top of which attached bubbler contg. 0.5 ml. 5% acetic acid, 2 drops sodium iodoplatinate soln., and 2 drops starch soln. When water admitted to generator, stream of carbon dioxide passed over material and through bubbler. If mustard gas present, appreciable blue color develops in reagent in 3 min. or less. Use of carbon dioxide for aspiration avoids any oxidation which may occur when air used, and also avoids interference by other gases.—*W.P.R.*

Water Supply in Wartime. Anon. Surveyor. (Br.) **99:** 346 (May 30, '41). Extracts from circular issued by Metropolitan Water Board. Supply of pure drinking water, sufficient for 2 or 3 days should be stored in clean, stoppered bottles, ready for use if supply to premises cut off by enemy action. Notification will be made if water supply to

premises impure. All water required for drinking should then be purified by boiling or chlorinating. One method: add 10 drops of chlorinated soda soln. to 1 pt. water, stir well and allow to stand not less than 5 min. Taste of chlorine can be removed by dissolving in it 1 or 2 crystals of hypo. If only water available contain particles of solid matter, should be strained through folded handkerchief or similar material before treatment. No cause for alarm if water supply to premises tastes of chlorine—indication that purity of supply safeguarded.—*H. E. Babbitt.*

Inter-Connections Solve Supply Problems. CHARLES H. CAPEN. Eng. News-Rec. **126:** 961 (June 19, '41). Connection of all sources of supply that may be reasonably joined, enabling pooling for common usage in case of need, one way of meeting accelerated demands of natl. defense activities. Inter-connection considered to be connection between any two supply systems, either at points on transmission mains or in distr. system, employed primarily for emergency purposes or occasional use. When such connection in daily or frequent use, termed a service connection. In northeastern N.J., pop. of nearly 3,000,000 served by 33 separate water sources, 23 publicly and 10 privately owned. Daily supply of nearly 300 mil.gal. retailed by 70 separate organizations. In '29, State Water Policy Com. formed, and included in authority was power to require interconnection of public water supply systems in public interest. Preliminary studies made but work delayed by financial stringencies and failure to secure approval of all concerned. Difficulties ironed out and preliminary report made in '39. Drought of that yr. forced some to use or construct inter-connections already pointed out as desirable. More than 300 existing and possible points of connection located and studied in northeastern N.J. and 32 selected as desirable, 10 being considered urgent. Hearings conducted but no pressure brought to bear. Chief difficulty, apportionment of cost. In addn. to these short interconnections, 3 trunk transmission lines totaling several mi. of 42–60″ pipe recommended. Two areas in southern N.J. also studied. In Camden area, 31 supplies, 21 publicly and 10 privately owned. Output of 32 mgd. delivered to 62 separate municipalities, total pop. being about 400,000. During Sept. '40 floods, fire pumper with 1,400′ of hose supplied one municipality for 2½ days. Inter-connection between 2 supplies would have sufficed. Unfortunately, same type of competition, jealousy and antagonism responsible for creation of existing situation is preventing alleviation of conditions. Until some state, or, if necessary, federal agency, orders such work carried out there is little likelihood of progress. Amicable persuasion ineffective.—*R. E. Thompson.*

Water Tanks and Water for Fire Service. ANON. Wtr. & Wtr. Eng. (Br.) **43:** 331 (Dec. '41).

"Brick reservoirs, for storing water ready for fire fighting in raids are superseding the rectangular containers made of steel plates, thereby saving metal. The shape of these brick reservoirs depends upon the sites where they are to be built. Where space permits they take the form of circles 24 ft. in diam., with the wall 4 ft. high. Such a reservoir will hold 10,000 gal. of water. Where the bases are porous, the reservoirs are being lined with reinforced concrete.

"Keeping static water supplies fluid during frosty weather so as to be available for fire service needs is a problem being investigated by the Ministry of Home Security. Since the war, ordinary water supplies have been supplemented by that in tanks in basements of bombed buildings, and containers in streets and open spaces. Anti-freeze chemicals or brine will be used to keep such water liquid, though it is pointed out that conditions vary considerably throughout the country."

Defense Training for Water Works Operators. SIDNEY S. ANTHONY, Editor. Jour. Me. W. Util. Assn. Spec. Ed. ('41) 158 pp. $1.00. Collection of papers presented on eng. defense training program conducted during Spring of '41 by Me. Water Util. Assn., as follows: The General Problem of Water Works Protec-

tion, E. SHERMAN CHASE; Effects of Sabotage on Utility Plants, FRANK E. SOUTHARD; The Sabotage Prevention Act (1941); Water Sources and Supply Lines, Including Protection Thereof, THOMAS R. CAMP; Water Distribution Systems in War Emergencies, GEORGE E. RUSSELL; Water Supply for Fire Protection, PERCY CHARNOCK; Development of Auxiliary Supplies, Including Inter-Connection of Adjoining Systems, HOWARD H. POTTER; Quick Repairs and Stock Supplies, MILTON THORNE; Power Supplies for Pumping Stations, NORMAN W. THURSTON; Co-operation Between Water and Fire Departments, JOSEPH W. RANDLETTE; Water Supply for Airports and Military Camps, SAMUEL M. ELLSWORTH; English Experiences in War Emergencies, HARRY U. FULLER; Requisite Qualities of Public Water Supplies, GORDON M. FAIR; Water Purification, ROBERT SPURR WESTON; Chemical and Bacterial Testing of Water, EDWARD W. MOORE; Chemical and Bacterial Testing of Water, Laboratory, J. ELLIOTT HALE; Use of Chlorine in Larger Plants, FRED S. GIBBS; Emergency Equipment for Sterilization and Its Application, HENRY ARMBRUST.—*Ed.*

Defense Production Will Produce Pollution. *Editorial.* MORRIS M. COHEN. Sew. Wks. Eng. **12:** 157 (Mar. '41). As Am. industry gears itself for greatest production spurt in history, problem of industrial waste treatment becomes pressing natl. matter. So much material going into vital task of defending our way of life means so much poln. discharged into streams. Now is time folly of destroying important resources must be recognized. Now, if ever, must be recognized that defense production will produce poln. During decade when industry took breathing spell, san. eng. progress not unemployed. Ready to handle greatly increased quants. of wastes and to solve intricate treatment problems. Encouraging evidence that industries willing and ready to provide proper treatment facilities, actually proud of their accomplishments and actively co-operating with state health officials. Conservatively, estd. will take a billion dollars to provide industrial waste treatment plants country needs. Poln. control agencies should grasp opportunity of national defense production to press for adequate industrial waste treatment. If situation properly handled, can use increased loading on sewers and streams as lever to swing much-needed constr. work. If industrial wastes treated during emergency days, certain to obtain complete treatment of domestic sewage upon return to normal living.—*Ralph E. Noble.*

Priorities in Chemicals. LAWRENCE BROWN. J. Am. Chem. Soc.—News Ed. **19:** 1248 (Nov. 25, '41). Priorities not devices of trade in time of peace, but instruments in aid of military operations in time of war; keystone of industrial mobilization and warfare. Sometimes seem motivated by unnecessary harshness and administered with reckless indifference to consequences. Fact is, motivated by necessity and administered by inexperience, both inescapable consequences of our way of life. Trained organization to supply skilled business mgmt. to all manifold ind. and business problems, a function of war machine with one objective. When German armies reached Atlantic ports, whole power relation of world changed. Shortages in chemicals include all solvents, drying oils and substitutes, all coal-tar acids, chlorine and many nitrogen derivitives. Heretofore considered our economy one of fuel and iron. In fact, based on chemicals. Thus derives situation of assigning various scarce metals to make this or that commodity, which cannot be made at all because some little chem. supply missing and likely to remain so. Incredible no. of important machines and devices cannot be operated or built without elec. insulation, plastics, lacquers, solvents, rubber, dyes, glues. These things in turn products of skill, intricate and vast machinery. Difficult to calc. amt. of chemicals entering into ship, plane, or tank constr.; or result on civilian economy if same amts. withdrawn therefrom. Confusion ensues and priorities break down in many cases. From this, system of complete allocation emerges. Latter contemplates month by month allocating entire production of

commodity in specific quantities. Raw chemical obtained for one is at expense of another with equally acute business need. In wartime, questions of fairness or monetary loss do not enter. This difficult system brings hardship and ruin to many, resulting in economic casualities of a war which, if lost, will produce same in defeat far worse than those suffered in fighting. This none too well realized because intimate interrelationships between military power and economic opportunity is something a near generation of Am. public opinion loathe to admit. Aggressors have tangible economic objectives as essential part of military program. Our forefathers proved guns a well tested method of acquiring wealth. Similar thread runs through chemical shortages. Tin, rubber, silk, tung oil, nitrates, chrome, bones, manganese, molasses, hemp, jute, pulp, glycerol, soap, oils, supplementary iron ore and copper normally brought by ship from every part of world. Loss of metallic imports, particularly non-ferrous metals, immediately of consequence in intense pressure of plastics. Jute, hemp and pulp affect paper, textiles and, above all, cellulose. Molasses means alcohol and all derivitives and related products. Lack of silk means pressure on acetate and phenol. Tung oil means phthalic anhydride; bones mean glue, nitrates mean ammonia. Condition is one of semi-blockade which compels recognition of historical fact that power is decisive factor in political and therefore economic events. Adams' "Atlantic System" was name for economic, military and naval relations holding world of '90's in orderly pattern. System rested on potential gun-fire seldom heard, giving long peace and unbroken lives. Seemed that wealth flowing from hard-won command of seas was source rather than product of it; that it was a phenomenon of nature rather than deliberately created order of society. Challenge shows it a man-made system after all, held together only by risk and expense.—*Ralph E. Noble.*

Lead Goes Under Priority Control. ANON. J. Am. Chem. Soc.—News Ed. **19:** 1174 (Oct. 25, '41). All domestic and imported lead supplies placed under full priority control by OPM in Gen. Preference Order M-38, setting up allocation system. Total defense and civilian requirements created shortage of domestic lead. Current consumption approx. 960,000 tons per yr. Increase anticipated. Current production, including that from foreign ores, not over 600,000 tons. Difference made up from scrap returned to industry and from imports. —*Ralph E. Noble.*

STERILIZATION

Factors Affecting the Germicidal Efficiency of Hypochlorite Solutions. A. S. S. RUDOLPH AND MAX LEVINE. Bul. 150, Iowa State College ('41). Study made of concn., reaction (pH), and temp. on germicidal eff. of commercial hypochlorite soln. ("B-K") to ascertain nature of survivor curves and influence on killing time (k.t.) for organism of const. resistance. Suspensions of *B. metiens* spores considered particularly applicable for study and preferable to vegetative cells because: (1) resistance more uniform than that of latter; (2) in view of high germicidal action of hypochlorites, vegetative cells die so quickly accurate detns. difficult; and (3) with long k.t's. required for destruction of spores, wide range of variation in concn., pH, and temp. possible, facilitating study of survivor curves. Suspensions of *B. metiens* spores consisted of 20-day agar slant cultures at 30°C. and suspended in Butterfield's Formula C water. Generally employed 24 or 48 hr. after prepn. Appeared to be no signif. difference, however, in resistance of spore suspensions after storage at 10°C. for periods as long as 240 days. If subsequent studies confirm observation, resistance studies would be facilitated to extent that a single spore suspension with known no. of viable cells could be used for long period. Observations on effective concn. on hypochlorite ("B-K") germicidal eff. restricted to solns. with

initial pH 10 and temp. 20°C. K.t's. observed were 121 min. for 25 ppm., 63.5 min. for 100 ppm. and 31 min. for 500 ppm. available chlorine (Cl_2). In general, quadrupling concn. reduced by about 50% time required to kill 99% of exposed spores. Doubling concn. available Cl_2 reduced k.t. about 30%. Reaction reported (pH 10) was initial of disinfecting soln.; owing to absorption of carbon dioxide, hydrogen-ion concn. increased during observations. As slight changes in reaction of alk. hypochlorite solns., range pH 9 to 10, found to affect markedly k.t., one distinctly longer than that observed would be anticipated in buffered solns. in which reaction would remain const. at pH 10. Effect of change in pH on germicidal eff. observed with soln. contg. 25 ppm. available Cl_2 at 20°C. for reactions pH 6, 7, 8, 9, 9.35 and 10, and with 0.25 *N* sodium hydroxide (NaOH) soln. of pH 12.86. Time required to kill 99% exposed spores varied from 2½ min. at pH 6, to 465 min. at pH 12.86. At high alkalinity, evidence indicated germicidal properties due to combined action of Cl_2 and NaOH. Therefore, result at pH 12.86 not suitable for inclusion in comparing effect of reaction on resistance of spores to chlorination. In range pH 6 to 10, however, spores not adversely affected by constituents other than Cl_2 and results obtained can therefore be considered due to change in reaction. For solns. in range pH 6 to 8, effect of changed reaction on k.t. relatively slight, time being 2½ min. at pH 6, and 5 min. at pH 8. In contrast, effect of change in reaction in range pH 8 to 10 very marked, indicated by rise in k.t. from 5 min. to 121 min. Thus, for 100-fold increase in hydroxyl-ion concn. in range pH 8 to 10, k.t. increased 20-fold. Changes in k.t. appear to be closely associated with changes in concn. of undissociated hypochlorous acid (HOCl), relative concn. of latter in range pH 6 to 8 being small compared to that in range 8 to 10. Thus, concn. of undissociated HOCl at pH 8 approx. 20% of that at 6, whereas at 10 it was but 1% of that at pH 8. Parallelism between concn. of undissociated HOCL and k.t. suggests former intimately associated with rate of disinfection by Cl_2 solns. Effect of temp. on germicidal eff. of hypochlorite observed at 20, 30, 35, and 50°C. with solns. contg. 25 ppm. available Cl_2 at pH 10. In general, k.t. reduced from 60 to 65% by rise of 10°C. Effect of temp. seemed to increase with rise in same; might be due partially to superimposed effect of change in pH associated with higher temps., for record of pH 10 was detd. at 25°C. Diln. of calcium hypochlorite ("B-K") soln. under investigation, when made with distd. water, found to increase its acidity. Soln. contg. 1,000 ppm. available Cl_2 showed reaction of pH 11.1; diln. with distd. water to 100 ppm. resulted in decrease in pH to 9.75, and further diln. to 25 ppm. yielded reaction pH 9.35. Commercial product apparently not well buffered in range pH 9 to 10. More dil. solns. showed greater germicidal activity, k.t's. for solns. contg. 25, 100, and 1,000 ppm. available Cl_2 being 35.5, 57, and 95.5 min. respectively. Although this at first appears to be anomalous, readily explained by change in pH caused by diln. As previously pointed out, in range pH 9 to 10, slight change in reaction will affect k.t. markedly. Quite evident, in this range, effect on k.t. induced by change in reaction exceeds effect of diln.; i.e., reaction coef. distinctly greater than diln. coef. Results illustrate quite clearly fallacy of employing concn. of available Cl_2 as sole criterion of probable effectiveness of Cl_2 as germicide. Nature of survivor curves and effects of concn. of available Cl_2, and of pH on concn. of undissociated HOCl, lend support to view that latter is active agent in hypochlorite disinfection. Survivor curves obtained in study indicate organisms did not die at const. rate. In every case definite lag followed by increasing death rates. Lag was shorter, but nevertheless distinct with more actively germicidal solns., i.e., at higher temps., concns. and acidities. In many instances survivor curves approximated straight lines beyond lag phase. Most apparent cause of increased k.t. lengthening of lag period. Velocity coefs. of death rate *K*, computed on assumption of logarithmic death rates, show death rate not const.,

but decreased rapidly when computed for successively longer periods of exposure. In many instances, however, K approached const. toward end of disinfection period. Two phases seem to exist in killing bacteria with hypochlorite: (1) penetration of active principle into cell, being more rapid with greater concns. of undissociated HOCl; and (2) chem. union of this principle with protoplasm, directly responsible for death of cell. Short lag in death rate obtained when theoretical concns. of HOCl relatively high indicates importance of undissociated latter as penetrating agent.—*Ralph E. Noble.*

Chlorination, an Effective Way of Sterilizing Water, Finds Its Recent Application in the Provinces. Pastor Echavez. Mo. Bul. Bur. Health. (Philippines) **20:** 15 (Jan. '40). Purif. of water by chlorination very recent method in Philippines. In '38, 40,503 cases and 16,034 deaths out of pop. of approx. 15,000,000 because of typhoid, dysentery and diarrhea-enteritis. After critical survey of situation, author feels that many cases due to polluted water supplies in provinces. Bact. surveys revealed that often so-called springs nothing more than seepages. Many provinces have facilities for making bact. surveys, but few have taken necessary steps to correct unsafe water supplies. Dist. health officers of Bohol in '37 first adapted method of chlorination and obtained gratifying results. Seasonal outbreaks of dysentery completely disappeared during year's operation of chlorination method. In '38, chlorination outfit set up during outbreak of dysentery in Anda and Mahini and no further cases reported. Above demonstrations along with discussion during dist. health meeting resulted in several other towns adopting chlorination method. Author concludes with plea for additional preventive work to be done. Includes in article diagram for emergency hypochlorite plant for small water supplies.—*P.H.E.A.*

Relation of Ammonia-Nitrogen to Break-Point Chlorination. A. E. Griffin and N. S. Chamberlin. Am. J. Pub. Health. **31:** 803 (Aug. '41). Experiences with super-chlorination in which it was found that increments of applied chlorine did not necessarily produce proportionate increments of chlorine residual, that in some cases they produce only slight increases and that in others they are attended by complete disappearance of residual, led to extended series of lab. and field expts. described. Data, when plotted, showed "hump and dip" chlorine residual curve which led to application of term "break-point" to lowest chlorine residual. Found that break-point most pronounced in water high in ammonia-nitrogen. Expts. conducted using Cl soln. and 0.50 ppm. NH_3–N, using NH_4Cl as source of the NH_3–N, and noting effect of pH. NH_4Cl placed in series of gallon samples with pH of 5.0, 6.0, 7.0, 8.0, and 9.0, treated with dosages of Cl varying from 0 to 11 ppm., kept at 45°–48°F., with residual determined by starch-iodide method on 500-ml. samples after 20-min., 2-hr. and 24-hr. detention periods. Results given as curves showing Cl residual, ammonia-nitrogen at various chlorine dosages for each pH. Optimum pH for removal of ammonium ions and reductions in chlorine under ideal conditions in neighborhood of pH 7.0 or 8.0; in actual practice found to vary from 6.5 to 8.5. Ratio of NH_3–N to Cl to reach break-point under ideal conditions approx. 1:10 toward 1:15 or beyond.—*Martin E. Flentje.*

Effect of Chlorination Upon Bacteria in Sewage. D. H. Hunter, N. W. Staalson and W. B. Sarles. (*Published in abstract only.*) J. Bact. **42:** 145 (July '41). Studies made of effect of chlorination upon total no. of bacteria in sewage and upon no. that ferment lactose, produce hydrogen sulfide from peptone, and from sulfates. Comparisons made between effects of: (1) 0.2 ppm. in excess of 30-min. chlorine demand; (2) 0.2 ppm. in excess of 15-min. demand; and (3) 20% of 30-min. demand. Chlorination to satisfy 30-min. demand of sewage no more effective than treatment needed to satisfy 15-min. demand. Reduction in total no. and in no. of various types of bacteria

ranged from 99.0 to 99.9%. Chlorination to satisfy 20% of 30-min. demand of sewage reduced total count approx. 22% and destroyed approx. 90% of bacteria that produce hydrogen sulfide from peptone, and 32% of such producers from sulfates, but had little or no effect upon lactose fermenters.—*Ralph E. Noble.*

Sterilization of Small Water Mains. ANON. Wtr. & Wtr. Eng. (Br.). **43:** 264 (Sept. '41). New mains or mains that have been repaired should be subjected to some form of sterilization before being brought into use. Conditions following air raid damage have made such treatment more than ever necessary. Usual method adopted for large mains is application of chlorine gas by one of now familiar portable chlorinating machines. Sterilization of small mains usually accomplished by addn. of sodium hypochlorite soln. at concn. up to 50 ppm. free chlorine distributed as evenly as possible throughout empty main by pouring into hydrants. Main allowed to stand full for ½ hr., then flushed. Disadvantages are: (1) may not be possible to empty main; (2) uneven distr. of chlorine throughout main; and (3) sterilization of branches on small mains difficult. Principle method to overcome these difficulties is to set up flow of water in main and inject known strength of chlorine into main at point upstream. For testing high concns. of chlorine used, portable testing outfit devised. Outfit includes 3 bottles of approx. 100 ml. capac. each, with 0.5-ml. pipette. One bottle contains ortho-tolidine; another is graduated at 50-ml. mark; and third contains potassium bichromate, color of which corresponds to 10 ppm. free chlorine. Directions state: (1) fill bottle to mark with water; (2) add 0.5 ml. ortho-tolidine; (3) shake and allow to stand 10 min.; (4) color must exceed that of standard.—*H. E. Babbitt.*

Main Sterilization on a Defense Job. HENRY J. ARMBRUST. Eng. News-Rec. **126:** 965 (June 19, '41). Quonset Point Naval Air Station provided with 2 water systems, one potable supply and other salt water supply for fire-fighting. Former consists of gravel-packed well and low-head motor-driven pump delivering through 8″ asbestos-cement main to concrete covered reservoir, from which water pumped into asbestos-cement pipe distr. system connected to elevated tank. Portion of distr. system in service while new sections being added. Dry hypochlorite placed in each length of pipe during constr., but samples collected from system showed presence of undesirable bacteria, although well water satisfactory in quality. Believed that movement of heavy equip. over new roads caused breaks which led to contamn. Decided, therefore, to chlorinate continuously, employing heavy-duty hypochlorinator. Notwithstanding fact that residual chlorine is as high as 1 ppm., no taste has developed. Equip. will be operated until entire system complete; then will be reserved for emergency use.—*R. E. Thompson.*

Covered Reservoir Contamination. L. A. MARSHALL. Ohio Conf. Water Purif., 20th Ann. Rept. ('40). p. 38. Bacteria which produce gas in lactose broth, only a few of which confirm as true coliform organisms, appear in finished water from both of Cleveland's filter plants during winter and early spring months following thaws and heavy rains. No. of these bacteria considerably reduced by application of chlorine but not by rather high dosages of chloramine. During Apr. '40, coliform index of water leaving both finished water reservoirs higher than that of water entering reservoirs, notwithstanding fact that post-chlorination dosage added at entrance. Part of increase, at least, explained by leakage through structural joints and cracks. Observations have shown that germicidal velocity of chloramine lower than that of chlorine, especially at low temps. Ammonia-chlorine treatment adopted primarily for prevention of chlorophenolic tastes and odors, additional benefits including possibility of maintaining higher residual chlorine values without causing chlorinous tastes. Found, however, that even with use of ammonia, residual chlorine not carried into out-

skirts of distr. system and that high degree of bacterial quality prevails throughout system whether or not ammonia used, and, if anything, somewhat higher when not used. If possible, ammonia should be applied only after chlorine has had sufficient time to effect sterilization. Procedure, however, would not prevent chlorophenolic tastes. Lab. expts. have indicated that either activated carbon or super-chlorination could be successfully substituted for chlorine-ammonia treatment in combating chlorophenolic tastes and odors. —*R. E. Thompson.*

Emergency Conditions in Water Chlorination. A. E. Berry. Eng. Cont. Rec. **54:** 30: 52 (July 23, '41). Chlorination of polluted water must be continuous and complete. Safety assured only when assumed that every drop of water is dangerously contaminated and that treatment must be administered accordingly. Necessary provisions to ensure continuity of chlorination include: (1) duplicate equip.; (2) sufficient chlorinator capac. to meet max. fire flow and highest chlorine demand of water; and (3) emergency portable equip. for dealing with sabotage, floods, poln. due to cross-connections, etc. Hypochlorite powders containing high concn. of chlorine in relatively stable condition have proved useful in emergencies and such powders might well be held in storage at treatment plants with equip. provided for application in case of emergency. Must be remembered that emergency situations develop unexpectedly and must be dealt with speedily. Importance of sterilizing new and repaired mains must not be overlooked. Cost of chlorination negligible compared to protection provided.—*R. E. Thompson.*

Modernized Chlorination at Water Purification Plant in New Toronto (Ontario). A. H. R. Thomas. Can. Engr.—Wtr. & Sew. **79:** 1: 21 (Jan. '41). Water supply derived from L. Ontario through intake extending 2,000′ from shore. Water treated with alum and passed through battery of 18 pressure filters, ammonium sulfate and chlorine being applied prior to filtration. Dosage of 4.5 lb. chlorine per mil.gal. gives residual of 0.2 ppm. in filtered water. Activated carbon employed when algae cause undesirable taste. Two new 50-lb. per 24 hr. automatic visible vacuum chlorinators recently installed. Chlorine cylinders (150 lb.) kept in basement room below chlorine machines. Pumpage averages approx. 4 mgd. Distr. system serves adjoining town of Mimico and village of Long Branch in addition to New Toronto.—*R. E. Thompson.*

The Sanitation of the Water Supply of Ankara. E. Gotschlich. Türk. Hıfzıssıhha Tecrübî Bîyol. Mecmuası. **1:** 2 :7 ('39); Zbl. Ges. Hyg. (Ger.) **47:** 197 ('40). Until Oct. '36 water supply of Ankara all obtained from springs in mts. to east and southeast of town. Spring supplies qual. and quant. inadequate. New reservoir at Çubuk, to northeast, supplies 23,000 cu.m. per day. As water is exposed to poln. 0.12-0.15 mg./l. chlorine added. *Esch. coli* present in more than 10% of samples of unchlorinated water, and in wet weather percentage rose to nearly 60. After chlorination *Esch. coli* no longer found in 6 ml. water, and total bact. count less than 10 per ml.—*W.P.R.*

Danger of Chlorine Gas. Freitag. Z. Ges. Schiess- u. Sprengstoffw. (Ger.) **35:** 159 ('40). Several instances of poisoning by chlorine described. Methods of treatment suggested. Venesection and oxygen inhalation recommended. Toxic action on man described as follows: 0.01 mg./l. can be breathed for several hr. without serious effects; 0.1 to 0.15 mg./l. lethal in 1 to 1.5 hr.—*C. A.*

Intoxication by Chlorine Gas. Olaf Römcke and O. K. Evensen. Nord. Med. (Norway) **7:** 1224 ('40). Case of chlorine intoxication caused by explosion of railway tank contg. 15 tons of chlorine described. In all, 85 persons intoxicated and 3 died, two with symptoms of pulmonary edema and one with bronchopneumonia.—*C. A.*

HEALTH AND HYGIENE

Gastro-Enteritis and Public Water Supplies. CHARLES R. COX. *A Symposium on Hydrobiology*. Univ. Wis. Press, Madison, Wis. ('41). p. 260. Reduced incidence of water-borne typhoid fever in past decade accompanied by decrease in typhoid carriers, but not in diarrheal diseases. "Gastro-enteritis" describes nonspecific disorders of gastro-intestinal tract. "Diarrhea" designates important symptom but not specific disease. "Dysentery" applies to disease from *S. dysenteriae* or *E. histolytica*. Should determine whether disease is caused by a dysentery organism, some other specific germ or an agent not detectable by present water or stool analysis technic. Accurate information on incidence of bacillary dysentery scant, due often to mildness of outbreak or termination of symptoms before proper investigation can start. Technic only partially satisfactory for isolating known pathogens from stool specimens and unsuited to isolation and study of *unknown* pathogens. Most outbreaks, therefore, recorded as unclassified gastro-enteritis. Great need for information regarding extent of endemic diarrhea, gastro-intestinal disturbances and prevalence of dysentery carriers before adequate control procedures can be developed. "Intestinal influenza" describes respiratory disorders of unknown etiology, spread by contact and accompanied by gastro-intestinal disturbances. Unknown virus suspected. Widespread distr. of cases suggests water as common vector. If supply contains coliform organisms at same time, conclude cases water-borne. If coliform organisms absent from water and stool specimens neg., conclude disturbance due to chem. irritants, decomposition products, algae growths, etc. Suspicion that some water-borne outbreaks due to so-called "intestinal influenza" weakens public confidence in water quality stds. and treatment processes. More study of cause needed. Evidence conflicting as to transmissability of virus diseases by water receiving present day treatment. Numerous filtered supplies cont. decomposing org. matter; numerous unfiltered chlorinated supplies contain algae and decomposition products thereof; and both types may, at times, contain coliform organisms when neither gastro-enteritis nor diarrheal diseases prevalent. Available evidence suggests water-borne gastro-enteritis due to temporary contamn. of supplies with specific pathogens of known or unknown nature. Search for latter, responsible for water-borne gastro-enteritis, hopeless for water works bacteriologists. Better to exam. large nos. of stool specimens. [But, author just stated present technic only partially satisfactory or unsuitable for this purpose.] and check pathogenicity with appropriate antisera from convalescents. Control of stream poln. and more general practice of sewage chlorination need emphasis as links in control of water-borne diarrheal diseases. Reported failure of conventional water chlorination to destroy intestinal pathogens may sometimes be due to survival of more resistant organisms, but in most instances would appear attributable to temporary ineffectiveness of treatment, or to lower germicidal effect of conventional Cl_2 doses. Factors detg. germicidal action of Cl_2 should be appraised for each supply in light of available reaction period and results secured with ortho-tolidine and flavon tests for residual Cl_2 with due regard to temp., pH, oxidation potential, Cl_2 demand, and turbidity of water. Results of flavon test should be used when appreciably less than those with ortho-tolidine; those of latter test when appreciably smaller. Much more extensive sampling of public water supplies needed as basis for treatment control, and to indicate more clearly quality of water actually delivered to public.—*Ralph E. Noble.*

The Problem of the Amebic Carrier. H. W. Y. TAYLOR. J. Trop. Med. Hyg. (Br.) **42**: 49 ('39). Carriers of amebic dysentery of "cyst-passers" numerous in all parts of world, even in countries

where amebic dysentery practically unknown. Many cases of chronic ill-health may be due to presence of *Endameba histolytica*. Danger of these cyst carriers causing outbreak of dysentery, particularly in tropics, emphasized, and instance at Moukden, Manchuria, described. Endemiology, mode of infection, and treatment of disease, and life history of the organism and its pathological effects, discussed. To prevent spread of organism, all servants should be given good sanitary living conditions, all those who handle food should be examd. periodically for evidence of infection, and human excreta should not be used for manuring vegetable gardens. —*W.P.R.*

Fluorine and Dental Caries. DAGMAR C. WILSON. Lancet. **I:** 375 ('41). Increased intake of fluorine before completion of calcification appears to be associated with relative immunity to caries. Statistical anal. of data from 2 groups of children in Somerset, 1 group with mottled enamel and other with none, showed neg. correlation between dental fluorosis and no. of carious teeth. —*C. A.*

A Study of the Relationship of Oral *Lactobacillus Acidophilus* and Saliva Chemistry to Dental Caries. FRANCIS A. ARNOLD JR. AND F. J. MCCLURE. Pub. Health Rpts. **56:** 1495 (July 25, '41). Dental caries experience rate and rate increase over 1 yr. determined in 127 white school children in Arlington, Va. Group classified according to deg. of dental caries activity during yr. Bact. studies of saliva made on individuals belonging to various clinical types. Close correlation found between dental caries activity and *L. acidophilus* nos. 3 specimens of stimulated saliva collected at 2- and 3-month intervals from same 12–14-yr.-old school children tested for: (1) total solids; (2) loss on ignition (organic matter); (3) ash; (4) percentage ash in total solids; (5) total nitrogen; (6) percentage N in total solids; (7) ammonia-N; (8) total N minus ammonia-N (corrected N); (9) corrected N in org. matter; (10) pH of isoelectric zone; (11) ppm. oxygen (O_2) consumed from permanganate; and (12) O_2 consumed from permanganate per mg. of organic matter in saliva. Data studied in relation to *L. acidophilus* nos. in saliva and to deg. of dental caries activity as detd. by clinical examn. No signif. relationship present. Method of formol titration for ammonia-N in urine applied to detn. of ammonia-N in saliva and reported as satisfactory rapid clinical method for saliva anal. pH of isoelectric zone of saliva protein found to vary among different salivas, but variation not correlated with caries activity or *L. acidophilus* nos. [*See also* Jour. A.W.W.A. **33:** 1298 ('41).]—*Ralph E. Noble.*

Fluorine in Etiology of Endemic Goiter. DAGMAR C. WILSON. J. Am. Med. Assn. **116:** 2632 (June 7, '41). Distr. of endemic goiter in Punjab and in England related to geologic distr. of fluorine and to distr. of human dental fluorosis (mottled enamel). Author does not suggest that presence of fluorine in drinking water only factor in causation of endemic goiter in particular regions; intervention of other factors operating against production of goiter may completely overcome action of fluorine in promoting it. For instance, weekly call by fishmonger's van at isolated village in coastal areas in Essex with high degree of human dental fluorosis has been described to counteract effects of local deficiency of iodine.—*John H. O'Neill.*

Effect of Chlorination of City Water on Virus of Poliomyelitis. J. E. KEMPF AND M. H. SOULE. Proc. Soc. Exp. Biol. & Med. **44:** 431 ('40). Knowing that virus of anterior poliomyelitis present in human fecal discharges, hence may contam. water supplies, authors investigated effect of chlorination on virus. Levaditi, Kling and Lepine found that 4 ppm. destroyed virus in cloudy tap water emulsion of infected monkey cord in 24 hr.; with clarified preparations $\frac{1}{10}$ of this sufficed, and they, without noting pH and temp. of emulsions, reported that chlorination by usual methods was virucidal. Authors prepared 10% emulsion of infected cord in saline and centrifuged it. 2 ml. of supernatant fluid added to 100 ml. of chlorinated water

(distd. water control set up). Initial chlorine content when virus added 0.58 ppm.; in 1 hr. had fallen to 0.1 when 2 ml. injected intracranially into monkeys; quadriplegia developed. Further expts. carried out. In munic. practice, residual chlorine of 0.1–0.2 ppm. for ½–2 hr. considered adequate for procuring safe water, but above expts. show that as high a concn. as 0.5 ppm. did not inactivate virus of anterior poliomyelitis in 1½ hr.—*B. H.*

Relation of Calcium Soaps to Staphylococcal Infections in the Skin. K. K. Jones and Marie Lorenz. J. Investigative Dermatol. **4:** 69 ('41). Calcium ions in oil-water mixtures containing bacteria facilitate passage of bacteria into oil layer. Bacteria viable for at least 2 wk. time in calcium soap precipitates. Incorporation of avirulent strains of staphylococci into calcium soap-oil mixts. increases ability of organisms to enter follicles and sebaceous glands and produce infection. Prevention of calcium soap formation in wash water and its deposition on skin, hair or clothing is an active prophylactic measure. Calcium soaps may protect bacteria against disinfecting and bacteriostatic agents.—*C. A.*

Lead and Arsenic Ingestion and Excretion in Man. Stewart H. Webster. Pub. Health Repts. **56:** 1359 (July 4, '41). Expts. made with 9 healthy adult orchardists who for 10 to 12 days ate apples sprayed with lead arsenate. Daily consumption, ranging from 0 to 10, averaged 3 apples per person. Anals. of fruit eaten showed potential intake of 1 to 26 mg. lead (Pb) and 0.34 to 6.8 mg. arsenic (As) per person per day. Analyses of daily urine and fecal specimens showed total 24-hr. output of Pb and As per man as much as 22.3 mg. and 2.43 mg., respectively. While quantities of urinary and fecal Pb and As excreted daily by different individuals varied widely, 24-hr. urinary Pb output per individual usually varied less from day to day. Results showed largest part of Pb eliminated in feces. Fecal As equaled or exceeded urinary As output in majority of persons studied; while in earlier expt. only traces of fecal As regularly found. Two explanations offered for difference: (1) Weathered spray residue may differ from pure Pb arsenate in phys. and chem. properties. (2) Individuals having chronic exposure to Pb and As compounds may differ from persons with only acute exposure in their utilization and excretion of As. Exptl. data insufficient to decide this question. Quantities of Pb and As excreted in 10 to 12-day period generally less than amts. estd. as ingested during same time. Conditions did not permit detn. of balance between intake and output. Several possible explanations for apparent retention of these elements suggested.—*Ralph E. Noble.*

Metallic Contamination of Hot Water From Cylinders of Base and Tinned Copper. L. Wilkinson and S. H. Wilson. Analyst (Br.) **66:** 322 ('41). Results of analyses of hot water taken from tinned and untinned copper cylinders which had been in use for periods from few days up to 7 yr., for heating soft New Zealand waters. Copper content of water taken from new cylinders never exceeded 0.8 mg./l., while that of water taken from cylinders more than 1 yr. old varied from < 0.1 to nearly 0.4 mg./l.; in no case, therefore, can water be considered dangerous to health. On other hand, water taken from some tinned cylinders and from cylinder in which solder exposed, found to contain as much as 0.5 mg. lead even after year's use; this amt. approaches danger limit and may have been due to use of solder for tinning. Strongly recommended that for tinning copper hot-water cylinders, tin used should contain $\not> 0.25\%$ lead.—*I.M.*

Electric Arc Welding. The Effects of Welding Gases and Fumes. J. Am. Med. Assn. **116:** 1618 (Apr. 12, '41). Welding as chief means of uniting metallic parts has extensively replaced bolts and rivets. Done either by electric spot heating and fusing under pressure, or by gas welding, or by arc welding. Heat of electric arc (around 6,500°F., or 3,593°C.) generates oxides of nitrogen, ozone and ultra-violet rays. From electrodes arise metallic fumes of manganese, chromium, nickel,

zinc, or magnesium. Coatings of electrodes may give off fluorides, silica, silicates and bitumens. Result multiple exposure. Over period of 21 mo., 253 rabbits and rats exposed to fumes generated by electric arc, bare ferrous electrodes being used. Zone of beginning danger from nitrous gases found to lie above 70 ppm. of air, and not in zone of 10 to 40 ppm. as claimed heretofore. Evidence against any widespread injury to welders operating under ordinary conditions, apart from confined spaces. Neither metal fumes nor ozone caused harmful irritation; but consideration should be given to rôles that may be played, in confined atmospheres, by oxygen deficiency, manganese, fluorides, zinc or chromium. Men exposed for 3 hr. to avg. concn. of 84 ppm. of nitrous fumes experienced no ill effects whatever. —*B.H.*

Emergency Preparation of Pyrogen-Free Water. J. C. Lees and G. A. Levvy. Brit. Med. J. (Br.) ('40). p. 430. Pyrogens produced by certain strains of bacteria liable to infect any water not kept absolutely sterile. Presence undesirable in water used for prepg. saline solns. for intravenous injection. Pyrogens not destroyed by autoclaving, but water free from pyrogens can be obtained by distn. Test for detecting pyrogenous water by measuring rise in temp. of injected rabbits described. Expts. on removal of pyrogens by adsorption described. Good results obtained by shaking water with powd. charcoal, but contact with granular charcoal not effective.—*W.P.R.*

Sanitary Engineers Needed in Health Departments. Abel Wolman and Henry Vaughan. Sew. Wks. Eng. **11:** 607 (Dec. '40). Abel Wolman. Difficult to isolate cause for lag in san. eng. admin. in municipalities behind that in the states. Within normal Am. city, virtually all environmental problems continue to confront administrator, while ghosts of environmental disease have been laid only in literature, not in fact. Recent reminders of environmental control problems are: startling typhoid fever epidemic in Ill. state hospital; typhus fever problems in Ga. and Md. cities; bubonic plague in Idaho; epidemics due to water supplies, milk and milk products, and other foods aggregating over 36,000 cases in '38. Broad field of activity at hand for munic. public health engr. Even cursory familiarity with avg. Am. city and its public health organization, however, discloses challenge of activity has not been met by city health officer or his budget makers. Perhaps major function is to review, assay and revise san. ordinances and codes to assure uniform, effective and intelligent program for control of environment, elimination of inadequate and obsolete regulations, simplification and integration of existing and new rules, and formulation of sound major policies. Am. cities literally hidebound and hamstrung with ordinances and codes, reasons for existence of which ceased in '90's. So much of expanding field of public health eng. requires eye for new, research must supply not only basis for control but stimulation of new activities. Engr. accustomed to objective comparison, expt. and observation should be militant leader in development of study and research undertakings. He should be in forefront in curiosity regarding new or modified methods of prevention and control. One of major obstacles to eng. practice within health dept. lies in hostility of other eng. agencies within municipality. Virtually all opposition stems from assumption that munic. eng. activities should be within dept. of public works. This is faulty, since primary reason for health dept. engr. is to bring to dept. of public works and all other eng. agencies health perspective generally not dominant in such depts. These **eng.** units have major concern with problems other than health, and not surprising that health aspects of work sometimes underestimated, because of pressure of manifold duties in specialized eng. fields. In increasing degree, public health engr. must relate activity to general physical and social problems of city. This implies on his part not only increasing familiarity with and interest in underlying phys. basis of his activity, but introduction of

disease and health aspects into city planning, housing, traffic control, water supply, sewerage and other munic. functions, by frequent contact with agencies responsible for same. HENRY VAUGHAN: Public health engr. must have buoyant personality and ability to command respect not only of fellow health workers, but of co-workers in bldg. and public service dept., water supply agency, and city engr.'s office. Respect for his judgment and professional standing will automatically create demands for consultation and joint direction and supervision of public activities which possess health signif. even though not administratively within jurisdiction of health dept. Many otherwise good health programs have been stamped with failure merely because mech. engr. who pumped city's water supply, or maint. engr. in some riverside industry could not conceive important health aspects of broken mains and leaky cross-connections, and neglected to submit problems concurrently to health dept. Employment of well trained, efficient, affable public health engr. will promptly bring such all-important health determinations to health dept. Architects will want advice on questions of housing, bldg. constr. and remodeling, expressed in terms of air space, light and heat to assure adequate ventilation, comfort and freedom from unwanted hindrances to development and maint. of positive health. Mech. engrs. will seek advice in laying out plans for industrial plants, hotels, and public bldgs. so as to avoid dangerous connections between polluted and safe waters, drains, and plumbing lines.—*Ralph E. Noble.*

Illinois Checking Public Water Supplies. ANON. Eng. News-Rec. **127:** 173 (July 31, '41). Of 663 public water supplies in Ill., 209 subject to contamn. Inspections and recommendations made, but installation of necessary safeguards depends upon local authorities. State has no power to enforce protection of munic. water supplies. Bills before State Senate concerning control of public water supplies and certification of operators. These would require all public water supplies to be maintd. and operated to produce assuredly safe water. 25 major water-borne epidemics traced to faulty public water supplies in Ill. since '20, involving more than 10,000 cases of dysentery and typhoid and more than 200 deaths.—*R. E. Thompson.*

Sanitation in the Province of Saskatchewan. J. G. SCHAEFFER. Can. Engr.—Wtr. & Sew. **79:** 5: 11 (May '41). Province came into being in '05 and first Public Health Act adopted by legislature in '09, direction of public health work being invested in Bureau of Public Health. Division of Sanitation formed in '21 and Dept. of Public Health in '23. Province now divided into 8 dists. with san. officer in each. Pop. about 1,000,000. Complete survey made annually of each municipality other than cities. System of scoring based upon health measures adopted creates friendly rivalry and produces excellent results. Constr. or extension of water works and sewerage systems must be approved by minister. 40 urban water systems, supplying 180,000 people. Surface sources used in 14 and ground water in 26. Eleven of surface waters treated by sedimentation, gravity or pressure filtration and chlorination, one by sedimentation and chlorination, one by chlorination only, and one by sedimentation only. Two ground water supplies treated for iron removal and chlorinated. Practically all sub-surface water highly mineralized, predominant salt being sodium sulfate, closely followed by calcium and magnesium sulfates. Some 3,000 samples of water analyzed annually and fully 40% have total mineral content of 2,000 ppm. or more—up to 8,000 ppm. not uncommon for test wells. This accts. in part for low consumption, per capita use averaging about 50 gpd., max. avg. being about 85. 23 municipal sewerage systems, serving 170,000 people, and 18 treatment plants, 10 being of activated sludge type. In '10, typhoid death rate over 41 per 100,000 while in '40 only 1.7. Municipalities required to submit water samples monthly.—*R. E. Thompson.*

Court Decision on Public Health. *Operation of city sewage disposal plant not enjoined.* (Texas Ct. of Civ. App.; *Mitchell et al.* v. *City of Temple et al.*, 152 S.W. (2d) 1116; decided Mar. 11, '41; rehearing denied July 2, '41.) Pub. Health Repts. **56:** 2275 (Nov. 21, '41). Suit, not for damages, but for injunction only, brought against Temple and certain officers to abate as nuisance, operation of city's sewage disposal plant. Alleged nuisance because: (1) escaping obnoxious and repulsive odors entered plaintiffs, houses, and (2) sewage from leaking sewer joints seeped into some of their wells, and into nearby ravines to cause breeding and collection of mosquitos and flies, and to develop obnoxious odors. Trial ct. denied temporary injunction. Appellate ct. said evidence was conflicting and that trial ct. entitled to consider comparative injury or "balancing of equities." In affirming judgment of trial ct., appellate ct. said much greater injury would result to Temple, of 15,000 pop., than to plaintiffs by completely enjoining sewage disposal plant operation. Plaintiffs undoubtedly have adequate remedy at law by way of damages.—*Ralph E. Noble.*

Court Decision on Public Health. *Order of State Stream Control Commission requiring city to construct sewers and sewage treatment plant upheld.* (Mich. Sup. Ct., *City of Niles* v. *Stream Control Com.*, 296 N.W. 713; decided Mar. 11 '41). Pub. Health Repts. **56:** 1027 (May 9, '41). Acting under provisions of law creating it, Stream Control Com. of Mich. ordered City of Niles to construct sewers and approved sewage treatment plant. Order followed unsuccessful efforts by com. to have city take care of its sewage. Statute authorized com. to make regulations and orders restricting polg. content of any waste material or polg. substance discharged into any lake, river, stream or other waters of state and to take all appropriate steps to prevent poln. deemed unreasonable and against public interest in view of existing conditions in any lake, river, stream, or other waters of state. City challenged order as unreasonable in view of unusual conditions existing in St. Joseph R. on which city located and into which it discharged untreated sewage. Unusual conditions complained of were large deposits of industrial waste and sewage discharged by certain Ind. cities and universities into St. Joseph R. immediately before it entered Niles.—*Ralph E. Noble.*

The Soil as a Source of Microörganisms Antagonistic to Disease-Producing Bacteria. SELMAN A. WAKSMAN AND H. BOYD WOODRUFF. J. Bact. **40:** 581 (Oct. '40). Soil contains no. of different types of micro-organisms antagonistic to various gram-positive and gram-negative bacteria. By enriching soil with specific bacteria, corresponding antagonists increase and can be isolated readily. Has been done most readily by using agar medium containing viable cells of specific organisms as *sole* available nutrient. Out of number of antagonistic organisms isolated from soil, two studied in greater detail, one, bacterium belonging to *Pseudomonas aeruginosa* group, and other, *Actinomyces*. These found to inhibit growth of several gram-negative bacteria, as well as and, even to a greater extent than of numerous gram-positive bacteria. Active substance produced by two antagonists found to be largely thermostable; passed through Seitz filter; removed by charcoal, and, partly at least, ether-soluble. Highly active preparations obtained, which inhibited, in very dilute solns., growth of *Esch. coli*, *Br. abortus*, and many other bacteria. Active substance also had strong bactericidal effect upon *Esch. coli* and *Br. abortus*; 1 ml. of preparations containing 0.4 mg. crude active substance killed aqueous suspensions of *Esch. coli* (215,000,000 viable cells) and of *Br. abortus* (68,000,000 viable cells.) Active substance found to reduce, in very low cones., bacterial pop. of natural substrates, such as milk. When added to agar, prevented development of great majority of soil bacteria and actinomycetes, but not fungi.—*Ralph E. Noble.*

SWIMMING POOLS

Swimming Pool Sanitation: *Neisseria catarrhalis* as an Index of Pollution. GEORGE O. TAPLEY AND MARSHALL W. JENNISON. *A Symposium on Hydrobiology*. Univ. Wis. Press, Madison, Wis. ('41). p. 355. San. quality of swimming pool waters generally measured by coliform indices and bacterial plate counts. These give no indication of contamn. with material related to skin eruptions, eye, ear, nose and throat infections more commonly reported than intestinal disturbances from this source. Mouth and naso-pharyngeal washings of bathers constitute part of surface scum. Swimmer contact with latter unavoidable. Authors suggest using *Neisseria catarrhalis* as index of san. condition of pool waters and describe direct plating or streak medium containing Bacto-heart infusion agar and phenol red indicator. From 2 pools in use with residual Cl_2 from trace to 1.0 ppm., 170 samples showed medium fairly specific for *N. catarrhalis*. Total colony counts always less than 100.0 per ml. Corresponding coliform content by standard procedure usually less than 1.0 per 100.0 ml. Surface colonies *N. catarrhalis* varied up to 28%, averaging 6% of total count. When Cl_2 residual 0.5 ppm., *N. catarrhalis* rarely found in 1.0 ml. Always present, however, when residual 0.1 ppm. Thus, even when fecal poln. kept within present stds. for swimming pools, naso-pharyngeal poln. whatever its importance, may be gross compared with coliform bacteria. Closer relationship appeared to exist between bathing load and *N. catarrhalis* than with coliform nos.—*Ralph E. Noble.*

Sanitation of Swimming Pools, With Special Consideration of the Chemical-Bacteriological Investigation of the Water. YOSIO YOKOTA, KENITI TYUDA AND MASARU HIURA. Mitt. Med. Akad. Kioto. (Jap.) **28:** 225 (in German), 296 (in Japanese) ('40). $KMnO_4$ consumption, bact. content of water and presence of coliform organisms gave good idea of increasing contamn. of water of swimming pool in girls' school, although water was purified by various methods. Griess reaction also revealed increasing contamn. but was less sensitive. Nitrite absent, but NH_3, nitrate and total hardness (both carbonate and non-carbonate, increased with increasing contamn. Pos. NH_3 and Griess reactions indicated contamn. with urine. D.O. of same water varied, but degree of satn. nearly always depended on temp. of water and degree of aeration caused by swimming. Water, when introduced into swimming pool, sufficiently pure for use, but, in spite of continuous purif. by various methods, used water contamd.; natural contamd. of pool water, however, reduced by purif. processes. As rapid change of water as possible indispensable.—*C.A.*

Public Health Aspects of Bathing Pool Sanitation. HAROLD B. GOTAAS. Pub. Works. **71:** 23 (Oct. '40). Unless attendants and bathers co-operate in keeping pool sanitary, other control measures will be largely ineffective. Need for personal hygiene on part of bathers stressed. Since certain changes occur in body during contact with water, bathers may become more susceptible to certain diseases. Eyes, ears, nose, throat, and skin usually affected, although disorders of skin usually contracted in unsan. dressing rooms. Gastro-intestinal diseases considered to be less frequently encountered. Bact. qualities and testing methods outlined. Constr. and operation as related to public health discussed.—*P.H.E.A.*

The Hygiene of the Public Swimming Bath. G. E. FRIEND. Baths & Bath Eng. (Br.) **6:** 11 ('39). At Christ's Hospital, West Horsham, Sussex, two swimming pools of 66,000 gal. and 22,000 gal. capac. Max. weekly load about 3,000 bathers. Water treated by filtration, aeration, and chlorination. Filter plant can treat 10,000 gpd. (7 A.M. to 5 P.M.), theoretically treating whole of water once a day. Spread, by infection in pools, of gastro-intestinal and respiratory diseases, and skin, eye, and naso-

pharyngeal infections discussed. Streptococci do not tend to multiply in bath water; bacteria of coliform group multiply rapidly. Control of bather and bathing routine important factor in prevention of epidemics.—*W.P.R.*

The Hygiene of the Public Swimming Bath. J. A. DAVENPORT. Baths & Bath Eng. (Br.) **6:** 12 ('39). Historical summary. With modern plant circulating whole contents of pool in 4 hr., dirt remaining in water at end of day not more than 22% of whole amt. brought in by bathers. Further improvement in condition of pools can be attained by reducing amt. of poln. introduced by bathers. Methods by which this can be achieved suggested.—*W.P.R.*

Schistosome Dermatitis as a Bathing Place Problem. JOHN E. MILLER. Am. J. Pub. Health. **31:** 305 ('41). Schistosome dermatitis or swimmers' itch not contagious but constitutes public health problem because of secondary infections. Life cycle of schistosomes, of which larvae of some species produce swimmers' itch, outlined. Larvae find man unsuitable host and die after penetrating skin. Report confined to problem in Mich., but infestation reported from 11 states, several Canadian provinces, England, and various parts of Europe. Control may be effected by killing snail hosts. Of 240 investigations made, 180 beaches found to be infested. Treatment consisted of application of 2 lb. copper sulfate and 1 lb. copper carbonate per 1,000 sq.ft. Soln. of 2 chemicals in proper ratio made in 60-gal. barrel in boat and siphoned out of barrel through 2 lengths of garden hose, one on each side of boat, with ends dragging on bottom. In shallow water, 1.5′, more practical to hand-sow pea-coal size copper sulfate crystals.—*P.H.E.A.*

Chemical Treatment of Lake Water to Control "Swimmer's Itch." W. A. RIDDELL. Can. Engr.—Wtr. & Sew. **79:** 8: 21 (Aug. '41). In '40, schistosome dermatitis widespread in Regina, Sask. Snails from which causative organism, the cercariae, emerge may be controlled by copper salts, but treatment of whole of Wascana L. not feasible at time, and copper sulfate would not have been effective for local treatment of swimming area, owing to rapid loss due to water currents and diffusion. Use of relatively insoluble copper salt which could be introduced in excess into swimming area and thus provide source of copper for some time beyond time of treatment indicated. Only salt available on short notice was powd. basic copper carbonate. This salt applied on surface of water in swimming area as thin suspension, dosage being 20 ppm. on basis of vol. of water in area, giving concn. of 6 ppm. dissolved copper and providing excess of solid which settled to bottom. Treatment eliminated organisms for about 1 wk. Itch reported during 3 periods only and on each occasion treatment had been delayed for day or two and in one case suspended for 1 wk. Copper content on each of these occasions had fallen to less than 1 ppm. No outbreaks occurred when water contained 2 ppm. copper. Toward end of season, cotton bags containing about 1 lb. copper carbonate suspended at 6′ intervals from buoy cable surrounding swimming area to provide "curtain" of dissolved copper around margin of area. As aid to control of snails and cercariae, attempt made to control weeds by use of sodium arsenite. No toxic effect on weeds noted, however, even with concns. of arsenic considerably higher than 1 ppm. recommended in report of Wisconsin Com. of Water Poln.—*R. E. Thompson.*

Comparison of Un-De-Chlorinated and De-Chlorinated Swimming Pool Waters. THOMAS M. RIDDICK. Am. J. Pub. Health **31:** 829 (Aug. '41). Comparison made of bact. samples from 8 large pools in N. Y. metropolitan area during period '36 to date. Pools in general have capac. of approx. 450,000 gal., are 75′ x 150′ in size, sterilize with NH_3 and Cl (with 1 exception), 3 use salt or brackish water. Filtration rates avg. about 3 gpm. and turn-overs avg. about 8 hr. Normal capac. bathing loads about 400 persons in pool water at 1 time with extreme peak loads, on only few days, of 800 bathers. Effect of de-chlorination of samples on collection with sodium thiosulfate shown graphically; de-chlorination increased 24-hr. Count 650% and

definitely confirms necessity for dechlorination of pool samples. Incubation for 48 hr. increased total count considerably in most cases. Increase, however, not uniform as some samples show increase in count of less than 100% while others increase several thousand per cent. Relationship between bathing load, chlorine residual and 48-hr. total count; between chlorine residuals and bathing loads at times when coliform bacteria found present, etc., shown. Author makes recommendations for changes in swimming pool bact. standards.—*Martin E. Flentje.*

Rendering Swimming Pool Waters Harmless With Silver Nitrate. G. S. Gan and K. M. Smirnov. Vodos. Sanit. Tekh. (U.S.S.R.) **15:** 12: 43 ('40). Lab. expts. showed high bactericidal effect for $AgNO_3$; similar results observed on treating water in pool with 0.5 mg./l. min. necessary to show presence of Ag several days later. In practice found expedient to treat 400 cu.m. of water, changed every 7 days, twice during this period, with total of 300 g. Procedure successfully used for 2 yr.—*C.A.*

Open Air Swimming Pools for Rural and Urban Places. Heinz Riedle and Ernst P. Stratemeyer. Gas u. Wasser. (Ger.) **83:** 501 (Sept. 28, '41). Differentiates between improved natural facilities for swimming and pools with water treatment plants. Only latter are justified from hygienic standpoint. Check on present installations showed that they do not as a rule satisfy reasonable san. stds. Natural facilities for swimming should not be improved with great costs, and concrete pools should be built only with treatment plants, except when there is available satisfactory thermal or salt water from springs, or cooling water free of oil from an industry. Poln. caused by: (1) inorganic or dead organic matter, (2) bathers and (3) living organisms. These groups described with drawings and microphotographs. Treatment of water includes recirculation, coagulation, filtration and sterilization. Further recommended that pool be equipped with foot bath, hot-water showers and toilets. Swimming pool that fulfills all hygienic requirements economically possible if made as small as possible for load to be expected. Such pool gives constant service during season and does not have to be shut down for cleaning and warming up of refill. Planning and operation should be under state control. Water should be tested for phys. properties, reaction, nitrate and nitrite, free CO_2, ammonia, chloride, manganese, iron, hardness, oxygen consumed, microscopic-biol. exam. and bact. test including Eijkman's test.—*Max Suter.*

The Control of Swimming Facilities in the City of Toronto. R. F. Heath. Can. Engr.—Wtr. & Sew. **79:** 6: 58 (June '41). Owing to economic conditions, fewer pools constructed in past than in previous decade, only 9 new installations being made, 7 by Bd. of Education. One pool constructed as integral part of apartment block, new departure in Toronto. Of 36 pools in city, 5 outdoor installations, 33 equipped with recirculating, filtering and heating systems and all employ chlorination, 16 having chlorinating apparatus. Of 5 outdoor pools, 4 use ammonia-chlorine treatment, which provides closer residual chlorine control. Almost universal employment of foot baths markedly reduced complaints about contraction of epidermophytosis and closer attention to proper use of showers resulted in noticeable improvement in phys. appearance of pool waters. Considerable improvement effected in bact. quality of waters. During 5-yr. period ending in '31, 45% of samples had bacterial counts below 250 per ml. with 9% contg. coliform bacteria in 1 ml., while in 3-yr. period ending in '40, 91.2% of samples had counts under 250 and only 0.6% cond. coliform bacteria in 10 ml.—*R. E. Thompson.*

A Swimming Pool Tank Built in a Lake. Anon. Eng. News-Rec. **127:** 234 (Aug. 14, '41). Construction of permanent swimming pool in Fountain Lake on New York World's Fair site described. Pool will accomodate 2,800 bathers and will be 50′ wide and 200′ long. Pool supported on piles and welded steel tanks used as forms for 2 deep diving areas.—*R. E. Thompson.*

HYDROLOGY, CONSERVATION AND IRRIGATION

Water Facilities Program Speeding Up. GEORGE PHILLIPS. Agric. Situation **25:** 14 (June '41). U. S. Dept. of Agric. Water Facilities Program intended to provide ample and dependable water to farmers suffering from deficient or uncertain supplies. Provides for improvement and rehabilitation of old systems and structures and building of new ones. Stock watering facilities built or improved include ponds, wells, power pumps, windmill pumps, springs and tanks. Irrigation works serving 123,543 acres include dams, wells, water-spreading systems installed and underground reservoir recharging systems under way. About 12.6% of cost absorbed by Govt., 59.9% financed by Govt. loan at low interest rate.—*Ralph E. Noble.*

The Water Resources of Transjordan. ANON. Engineering. (Br.) **151:** 181, 244 (Mar. 7, 28, '41). Transjordan irregularly-shaped area of about 35,000 sq.mi. extending eastward from Jordan Valley into Syrian desert. Estimated pop. 325,000, of which less than half is settled, remainder being wholly or partly nomadic. Oil pipe line from Iraq to Haifa runs for about 200 mi. through north Transjordan. Region would appear to be capable of development to far greater extent than has been realized. Land, however, almost entirely desert. Practically all settlements within 40 mi. of western boundary owing their existence to natural water sources feeding Jordan and Dead Sea. Jewish partisans assessed in millions no. of new settlers that Transjordan could support; by contrast, estimate only few thousands, by opponents of Jewish immigration. Funds for a hydrographic survey of Transjordan made available, in 1937, to Palestine Royal Com. Uncertain views held about feasibility of developing irrigation find some justification in topographic features of country. Climate divided into two clearly defined seasons: relatively wet, cold winter from Oct. to May, and hot, rainless summer. Recorded max. temp. 112°F. in Ghor lands, with min. of 29°F. on Transjordan plateau. Snow falls regularly in many inhabited districts of hills. Prevailing wind from west throughout summer and blows with remarkable regularity. Annual rainfall of 16″ over coastal plain, rises to 32″ at crest of Palestine hills, but falls off rapidly to little more than 8″ in Jordan Valley. Conditions so vastly different from those commonly experienced in Britain as to warrant close attention, since they constitute fundamental factor in appraisal of Transjordan's water resources. Picture of rainfall resources not strikingly optimistic. Not made any brighter by evidences of general decline in rainfall over whole region, widely noted by inhabitants during past 40 yr. Plentiful Biblical allusions leave little doubt that type of climate remained substantially unchanged. Hydrographic survey comprised 2 major divisions, concerned, respectively, with measurement of flow in springs and streams, and exploration of sub-surface waters. Potential water supplies compactly summarized as follows:

SOURCE		QUANTITY *million cu.m. per annum*
Rainfall supply to Transjordan Basin		4,472
Ground water flow from Transjordan Basin		282
Direct runoff from Transjordan Basin		299
Flow of River Yarmuk		
Ground water	254	
Direct run off	226	
Total		480
Flow of River Jordan at outlet from Lake Tiberias		540
Total		6,073

Rainfall of 8″ per annum is min. with which dry farming, without irrigation, possible. Area over which this min. exceeded, about 3,500 sq.mi., but only about ½ arable. Irrigated area lies mostly within Ghor lands adjoining Jordan. Water estimated at about 8,500 million cu.ft. per annum. Outside

these areas, development offers little promise of supporting any significant increase of pop. Another aspect is prevention and reclamation of land denuded by erosion. Equally unpromising is possibility of conserving direct runoff for irrigation. Possibilities of low-lift pumping from Jordan limited by available area of suitable land. High-lift pumping from Jordan and from tube wells can scarcely be considered nationally profitable. Control of existing irrigation systems in Ghor, and construction of suggested Yarmuk Canal, both appear profitable and practicable possibilities. Would secure 5,000 million cu.ft. of irrigation water annually in region where crops can be grown.—*H. E. Babbitt.*

Water Management in Africa. KARL LAUX. Gas u. Wasser. (Ger.) **83:** 409 (Aug. 24, '40). In southwest Africa, water must be obtained from wells to 330′ deep. Pumping is by windmills, thanks to 5 to 6 hr. regular wind daily, at rate rarely over 2,500 gal. per hr. For irrigation with ditches, 5 to 10 times as much water is needed as is required for plants. Fine soil is pulled into the soil, sealing it for aeration. Better results are obtained by raining the water in small amt. over ground, and larger districts can be cultivated. As climate of district is healthy, about ¼ of whole land can be made cultivatable with new system of irrigation. In mountain districts artesian wells can be used as source of water and even possibilities for reservoirs are present, but these require careful hydrologic study, as only about 10″ of rainfall occur and evaporation is heavy. In Transvaal, water conditions are somewhat better, owing to presence of year-around streams. Probably construction of reservoirs has been overdone. Near Mt. Kilimanjaro, water is plentiful in upper reaches of streams but has to be brought to plantations during dry season. System of raining irrigation water prevents flushing away of fertile top soil. Light weight pipe (transite) must be used for easy transportation. Installation of water power would help plantations. Great irrigation works on lower Nile are marvels of water technique, but no more could be built at present, owing to costs.—*Max Suter.*

Conservation of Our Water Resources. S. C. CLARK. Tex. W. W. Short School **22:** 76 ('40). Conservation of Tex. water resources problem of efficient development and wise utilization. Adequate laws available for conservation and utilization of water from streams, but none for control of ground water supplies by state regulation. Question of future water supplies for cities constantly facing all munic. development. Two-thirds (over 2,500 towns) of urban pop. depend upon ground water supplies. —*O. M. Smith.*

Computation of Flood-Flows by Slope-Area Method. A. H. DAVISON. Civ. Eng. **11:** 246 (July '41). Immediate objective of discussion to present method for accurate determination of flood discharge and to provide sound explanation of attendant factors. Slope-area method of computation can be applied if data obtained at site include survey of available high-water marks and suitable cross-sections of stream channel. Analysis of data by application of Chezy and Kutter formulas, or by Manning formula, usual procedure. Essential principle is that there can be but one value of discharge that satisfies data. [Illustrative example, based on July '35 flood conditions on Glen Creek, N. Y., solved.] Minimum of 3 cross-sections necessary to any solution. Example taken to illustrate method gives more clean-cut results than can be expected when circumstances are complicated by backwater effects. Factor n is referred to as "coef. of roughness," a misnomer in writer's opinion; it is really "coef. of circumstances." An assumed value of n cannot contribute to accurate conclusion. Important factor n should be calculated just as is any other important factor affecting eng. solution, and it almost invariably proves higher than value likely to be assumed. Error inherent in assuming friction slope s as equivalent to surface slope not important if values of avg. velocity from section to section are low enough to result in small

differences in velocity-head values. *Discussion. Ibid.* **11:** 551 (Sept. '41). JOHN C. HARROLD: Answer obtained by Davison in example was 17,800 cfs. Writer has attempted to show by computations that any discharge can be made to fit data just as well as value obtained by author. Fundamental error in author's assumptions appears to be that n for a reach is equal to avg. of n's at ends of reach and that s for a reach is equal to avg. of s's at ends of reach. Writer's opinion that since Manning and Kutter formulas have been derived as means of determining friction losses for reaches, they should not be applied to points. *Ibid.* **11:** 612 (Oct. '41). R. W. DAVENPORT: Davison's solutions based on assumption that slope of water surface essentially uniform through two reaches. Anyone who has seen a steep natural stream in high flood will appreciate weakness of this as a rigid assumption. Davison proposes to apply exact math. solution to data of such low precision as are usually available for slope-area determinations. Such procedure may produce seriously misleading results. Computation of discharge by slope-area method is not well standardized and such studies as are presented are helpful in standardizing practice. WM. S. EISENLOHR JR: Slope-area method of determining flood discharge never exact, even under best conditions. For this reason computation procedure proposed unsuited for general practical use as it requires precision not justified by basic data. As result of refinement in computations dictated by method and consideration of all combinations that satisfy assumed conditions, 5 values of discharge varying from 8,600 to 19,100 cfs. obtained; but no solution within 1,000 cfs. of author's solution. Should also be noted that Davison has assumed full recovery of velocity head in expanding reach. Most authorities agree that this never occurs.—*H. E. Babbitt.*

Erosion Control for Reservoir Protection. HARRY E. REDDICK. Soil Conserv. **7:** 77 (Sept. '41). East Bay Munic. Utility Dist. (non-profit organization) supplies water for domestic and industrial use to 500,000 pop. in wide area. Soil Conserv. Service agreed to develop erosion-control program on watersheds surrounding local reservoirs for reducing sedimentation rate in storage basins. Four reservoirs have combined capac. of 101,550 acre-ft. Survey of San Pablo reservoir, '39, showed 2.63% loss of total capac. by deposited sediment in 21 yr. Sediment sources are: (1) natural water courses, (2) accelerated or man made gullies, (3) private agric. lands, and, (4) landslides and slips. Sediment movement caused by increased runoff resulting from construction of roads, bldgs., etc., improper land use and cultural practices, seasonal distribution of rainfall, and character of soil and topography. Conserv. program designed to reduce gradients and minimize abrasive action in streams by means of check dams, and to reduce erosion on watersheds by plantings.—*Ralph E. Noble.*

Multiple-Purpose Reservoir Operation. *Part I. In Single or Independent Units.* NICHOLLS W. BOWDEN. Civ. Eng. **11:** 292 (May '41). Decade ago not uncommon to hear that provisions for flood control and hydro-electric power production in same project incompatible. While multiple-purpose projects may not yet be generally accepted by eng. profession as effective for controlling water, their proponents can point with considerable assurance to definite trends in planning, and to actual operating records that are favorable to multiple-purpose theory. Sacandaga Reservoir for Hudson River Regulating Dist. has now been in successful operation for 10 yr. Tygart multiple-use reservoir on tributary of Monongahela, about 150 mi. above Pittsburgh, serves many useful purposes. Act providing for gigantic Boulder Canyon project requires that reservoir be operated for 5 major purposes—river regulation and flood control, irrigation, silt control, power development, and domestic water supply. Marked change of opinion recently among American engrs. as to the efficacy of multiple-purpose projects and desirability of constructing them wherever practicable. Even more indicative of trend is very great increase in the number of such projects that have been and are being built. This type should continue to grow in popularity especially because of the possibilities of greater total returns than would accrue from a single-purpose

project even if more efficient. *Part II. In Combination Systems With Several Units. Ibid.* **11:** 337 (June '41): Since projects of TVA form system of reservoirs within single river basin, they are interrelated and must be operated as unit. In view of lack of data on operation of system of multiple-purpose reservoirs, such as that in Tennessee Basin, has not been possible to turn elsewhere for guidance; neither has any generally accepted theory of operating such a system been available. All completed main-stream projects of TVA much alike and operated in similar manner. In each case, flood storage superimposed on navigation pool, which is fixed at elevation needed to furnish suitable depths in pools, over upper miter sill at entrance to downstream lock and over lower miter sill at upstream lock. Navigation pools become minimum reservoir levels and may not be encroached upon for other purposes. They fix min. headwater and tailwater elevations for turbines at each project. While navigation and power purposes require careful planning to accomplish the best regulation of flow, particularly during droughts and floods, most difficult and exacting operation is that for flood control. On the approach of flood, storing is begun in tributary reservoirs and continued as long as necessary to withhold undesirable contribution from flood peak. Main-stream reservoirs held at about min. elevations for navigability at upper ends. No two floods exactly alike, hence no stereotyped method of reservoir operation for effective regulation can be prescribed in advance. Elements essential to successful operation of multiple-purpose reservoir systems include: (1) accurate weather forecasts, particularly of precipitation, as far in advance as possible; (2) accurate measurements of precipitation and runoff at selected key stations; (3) dependable and prompt transmission and assembling of these data at central point and their quick and accurate translation into present and prospective runoff; and (4) constant attention and prompt decision, particularly in time of flood, in determining dispatching or storing of water in system by competent, experienced hydraulic engr.—*H. E. Babbitt.*

Mechanical Water Level Recording Instruments. A. LINFORD. Civ. Eng. (Br.) **36:** 491 (June '41). Simplest form of level recorder float-operated, in which copper float attached to cord passing over pulley wheel operates indicating or recording mechanism. Accuracy obtainable with these instruments depends on power available in float to operate recording mechanism and to overcome starting friction. Suitable protection of float must be provided to prevent side movement due to currents and wind. Mercurial type level recorder consists of two chambers filled with mercury interconnected at lower ends to form U-tube. One chamber open to atmosphere while second connected to point below lowest water level to be measured. Variations in water level cause alterations in pressure on mercury surface of sealed chamber. Indicating and recording of levels in wells evolved air-reaction method in which small open-ended cylinder lowered into well and connected to recording instrument, at ground level, by capillary tube. Stream of air passed down tube and issues out of bottom of bell—thus balancing pressure at that point where it is equal to that due to depth of water. Use of air as pressure transmitting medium adopted in diaphragm type of instrument. In this system, box, covered with very flexible membrane, replaces air bell, and, in similar manner, placed below lowest water level. Somewhat special level recording instrument electrically connected to normal Post Office telephone system. As soon as it is called up by correct number, local circuit starts gramaphone motor and allows needle to descend on appropriate groove in gramaphone record. Water level appertaining at that moment is announced.—*H. E. Babbitt.*

A Portable Electric Water-Depth Gage. H. G. WILM AND M. H. COLLET. Civ. Eng. **11:** 305 (May '41). To meet growing need for portable instrument capable of indicating accurately water depths in wells and channels over considerable range, gage designed. As in other electric point gages, distance of water surface from reference point measured with plumb-bob suspended on graduated steel tape. Contact of bob with water surface closes electric circuit which activates

needle of milliammeter. Gage, for which public patent has been applied, developed by U. S. Forest Service and used successfully on several experimental watersheds in West.—*H. E. Babbitt.*

Consumptive Use of Water for Agriculture. Robert L. Lowry, Jr. and Arthur F. Johnson. Proc. A. S. C. E. **67:** 595 (Apr. '41). Transpiration and evapn. together acctg. for practically all consumptive use of water, have been shown by exptl. investigations to be influenced by climatic factors, of which temp. gives one of better correlations. Study made for purpose of obtaining working basis for estimating probable annual consumptive use of water on projects under investigations for conditions of full development with adequate water supply. In basic sense, consumptive use is ". . . quantity of water, in acre-feet per cropped acre per year, absorbed by crop and transpired or used directly in building of plant tissue, together with that evaporated from crop-producing land." Studies made for purpose of determining consumptive use of water include tank expts., plot and farm expts., and project and valley studies. Although small-scale expts. for determining consumptive use are of questionable value in some cases, have been of great value in pointing out importance of transpiration and evapn. as chief processes in consumptive use, and influence on these phenomena of meteorological factors. Present study predicated on correlating consumptive use of water to effective heat during growing season. On each area used in study, adequate records or estimates obtained of surface inflow to, and outflow from, area; of changes in surface and ground water storage, if appreciable; and of precipitation. In most cases of areas studied, shortages of water supply occurred in one or more years of period of record. When dry years omitted ground water recharge enters into mean as consumptive use. Believed preferable, therefore, to include all years of record in mean and to add correction factor to water supplies in low years sufficient to make them adequate. As used in paper, term "effective heat" is accumulation, in day-degrees, of max. daily temps. above 32°F. during growing season. Growing season frequently considered time between killing frosts. Areas included in study represent practically entire range of growing conditions and types of agriculture found in U. S. Essential feature of water supply investigations of irrigation project is determination of its water requirement. Annual consumptive use is convenient approach in this determination. From relation developed in paper, possible to estimate consumptive use from temp. data, which are usually available. Appendix includes description of areas studied.—*H. E. Babbitt.*

Ground Waters and Their Use for Irrigation in Arizona. H. C. Schwalen. Ariz. Sew. & W. W. Assn. Bul. **3:** 12 (Dec. '40). Ground waters of immense importance to agriculture in Ariz. Approx. 640,000 acres, less than 1% of total area of state under irrigation. During past few years, greater portion dependent either wholly or in part for water supplies on ground water. Therefore important to conserve ground water. Avg. draft from ground water reservoir over period of years cannot safely exceed avg. annual recharge to that reservoir. Violation of principle results in lowering water tables causing higher lifts, deepening wells, lowering pump settings, and larger power units with consequent financial loss. Outline of number of wells or pumping plants in operation and estimated acreage irrigated in '40 given.—*P.H.E.A.*

Conveyance Losses in Irrigation Canals. E. B. Debler. Civ. Eng. **11:** 584 (Oct. '41). While losses cannot be eliminated, partial reduction may be within reach at cost much less than resulting saving in storage costs. Reduction of water losses from canal prisms must be secured either by means of skin of impervious material or treatment of underlying canal material to reduce percolation. Skin treatment by means of bentonite and other materials of similar type in experimental stage, permitting no fixed opinions. Treatment of canal surfaces by impregnation with chemicals and passage-closing materials received some attention and may deserve more.—*H. E. Babbitt.*

HYDRAULICS

On the Four Régimes of Open-Channel Flow. J. M. ROBERTSON AND HUNTER ROUSE. Civ. Eng. **11:** 169 (Mar. '41). Statements to effect that there are only 3 stages of open-channel flow may be traced through more than decade of hydraulic literature. Literature of period contains sufficient analytical material to indicate fallacy in statements, but exptl. evidence to support material does not seem available. Simple matter to plot on graph of y versus V, line $\mathbf{R} = Vy/\nu = 500$, which should mark the border between zones of laminar and turbulent flow for various values of y and V. Likewise, line $\mathbf{F} = V/\sqrt{gy} = 1$, which separates zones of tranquil and rapid flow, may be plotted on same graph. While Froude no. (**F**) applies only to flow with free surface, in which gravitational action may be effective, Reynolds no. (**R**) is as applicable to free-surface flow as to flow that is entirely confined within conduit walls. (Other nomenclature: V = avg. velocity of flow; y = depth of flow; ν = kinematic viscosity; and g = acceleration due to gravity.) Intersection of such lines indicates 4 regimes of flow: (1) tranquil-laminar; (2) rapid-laminar; (3) tranquil-turbulent; and (4) rapid-turbulent. Regimes 1 and 2 very seldom observed in open-channel hydraulics owing to the low rates of flow necessary to their existence. Flow of rain water down roof or sidewalk more apt than not to illustrate tranquil laminar or rapid laminar regime. Slope, S, necessary to yield uniform laminar flow in very wide channel may be computed from $S = \frac{3\mu V}{\nu y^2}$; and for uniform turbulent flow in smooth channels of very great width from $S = \frac{0.059V^2}{(Vy/\nu)^{1/4}2gy}$, in which μ is dynamic viscosity, ν is specific weight. (If variation of y with V in accordance with these relationships shown graphically for several different slopes, lines for laminar and turbulent regimes would intersect approx. at $Vy/\nu = 500$. Similar plots of Poiseuille and Blasius equations in terms of hydraulic radius (R) would intersect at about $VR/\nu = 300$. This would indicate that corresponding critical Reynolds no. for very wide channels is higher than that for pipes, simple proportion yielding a value of around 800. In connection with criterion for existence of hydraulic jump, if depths of flow relatively small, both surface tension and gravitational attraction must be included in expression for elementary wave velocity. Fact that waves may exist often tends to conceal fundamentally familiar nature of regime. Since both Froude and Reynolds criteria must be used in designating four regimes of open-channel flow, certain anomalies in present-day nomenclature will soon become apparent. Considerations appear to leave only two general possibilities: the choice of terms associated with gravity-wave, similar to "subsonic" and "supersonic"; or terms that are inherently descriptive as "laminar" and "turbulent." Since ultimate choice of nomenclature must depend upon popular opinion among hydraulic engrs., hoped that further thought on subject may be stimulated by these comments. *Discussion. Ibid.* **11:** 312 (May '41). JOHN M. HALEY AND M. R. LEWIS: Also have noted existence of "rapid laminar" flow in expts. on hydraulics of very small streams. In no. of cases have been able to change flow back and forth between turbulent and laminar at will, with the same bottom slope and quantity of flow. In each case, Reynolds no. has been larger for laminar flow, because of higher velocity, than for turbulent flow.—*H. E. Babbitt.*

Velocity Distribution in Open Channels. VITO A. VANONI. Civ. Eng. **11:** 356 (June '41). For case of uniform, two-dimensional open-channel flow:

$$\frac{V - V_{max}}{\sqrt{gds}} = \frac{2.3}{k} \log \frac{y}{d}$$

in which V is velocity at any level; d, depth of flow; S, slope of channel; and k,

constant having value of about 0.4. Fact that in streams, max. velocity does not occur at surface precludes possibility that velocity distr. is strictly logarithmic. Relations similar to those developed for two-dimensional channels can also be derived for circular pipes.—*H. E. Babbitt.*

Flow in Effluent Troughs. RANDOLPH H. DEWANTE AND E. RALPH STOWELL. Civ. Eng. **11:** 212 (Apr. '41). To secure quantitative evaluation of discharge to be expected from troughs with either notched or continuous crests, writers undertook series of expts. in labs. of Univ. of Calif. Found by logarithmic plotting that discharge, Q, varied with $y^{3/2} = (y_1 + sL)^{3/2}$ where y_1 is depth of water in ft. at closed end of trough, s is bottom slope of trough, and L is the length of the trough. This led to formula $Q = C_1 b y^{3/2}$, in which b is width of trough in ft., and C_1 is constant whose avg. value found to be 2.32. Formula applies only to rectangular troughs of constant width. May be extended to design of troughs with variously shaped inverts or bottoms by use of equivalent rectangular section. Second formula applicable to notched troughs also developed: $Q = NC_2wH$, where N is no. of notches in trough, w is width of notches, H is head on notch crests in ft., and C_2 is constant whose value is 3.40. Bottom slope important only when it exceeds critical. Formulas would probably be of greatest advantage in checking design. At best, they are intended merely to serve as guide to designer.—*H. E. Babbitt.*

Effects of Curvature in Supercritical Flow. WARREN E. WILSON. Civ. Eng. **11:** 94 (Feb. '41). Work here described carried out with original intention of establishing principles to be used in design of transitions for rectangular open channels. After some progress, aims restricted to include only exptl. establishment of fact that sub-hydrostatic pressures did exist, and analytical investigation of effect of non-hydrostatic pressure distr., resulting from vertical accelerations of liquid particles, on depth change along vertical wall. Non-hydrostatic pressure within body of liquid characterized by factor K in following way. If depth of water is d, if m is unit-mass of water, and if g is acceleration due to gravity, then total pressure on a vertical plane of depth d, extending from surface of the water to bottom, and of unit-width, given by $P = \frac{Kmgd^2}{2}$. Characteristics of flow with non-hydrostatic pressure distr. in general way same as those of flow with hydrostatic pressure distr. May be shown that expression for rate of change of depth with respect to angular change in direction by wall is given by

$$\frac{dd}{d\theta} = \frac{d}{4K}\left(-\frac{dK}{d\theta} + \sqrt{\left(\frac{dK}{d\theta}\right)^2 + 16K\mathbf{F}}\right)$$

in which θ is angle between wall and channel, and $\mathbf{F}$ is Froude's no., $\mathbf{F} = u_o^2/gd_o$, in which u_o is avg. velocity and d_o, depth. Integration of above equation not yet proved feasible, but certain characteristics of flow with non-hydrostatic pressure distr. may be determined by equating to unity ratio between quantity $\frac{dd}{d\theta} = \mathbf{F}^{\frac{1}{2}}d$, an equation for large values of $\mathbf{F}$ derived from work of Knapp and Ippen, and $\frac{dd}{d\theta}$ as given by above equation. For this condition, gradient $\frac{dd}{d\theta}$ is identical for both hydrostatic pressure distr. and non-hydrostatic. Criterion for this condition is:

$$\frac{dk}{d\theta}\,\frac{1}{1-K} = 2\sqrt{\mathbf{F}}$$

Now if combination of factors on left-hand side of this equation is greater than $2\sqrt{\mathbf{F}}$, depth gradient will be less than normal gradient. If left-hand terms less than $2\sqrt{\mathbf{F}}$, depth gradient greater than normal.—*H. E. Babbitt.*

Theoretical Discharge Coefficients for a Weir of Ogee Profile. I. NELIDOV. Civ. Eng. **11:** 40 (Jan. '41). Among first requirements for design or analysis of spillway are depth and energy content

at weir crest. Adding critical depth to critical velocity head does not check head on weir. To illustrate, consider rectangular weir of ogee profile with head of $H = 5.0'$ and coef. of discharge of $C = 3.5$. Then energy content will be $d_c + h_{vc} = 3.33 + 2.15 = 5.48'$, which is not equal to $H = 5.0'$. Cause of discrepancy lies in fact that coef. $C = 3.5$ can be obtained only when flow over weir is curvilinear, while limits for coef. C for rectangular weir, without losses, are between 3.00 and 4.18. Derivations will be given for coef. of discharge, C; depth on crest, d; radius of weir profile, r_i; and pressure on surface of weir, p_i; in terms of coef. of non-uniformity of velocities, k. Consider weir of radius, r, with effective head, H_o, obtained from total head on weir, H, by deducting entrances losses, h. Denote $n = p_i/d$, ratio of pressure on weir to depth. For control section, $n = 1.0$. For aerated, sharp-crested weir, $n = 0.0$, pressure on lower nappe being atmospheric. If ogee weir has same radius as lower nappe of sharp-crested weir, $n = 0.0$ likewise. Coef. of discharge, C, expressed in terms of total head H, will be

$$C = C_o\left(\frac{H_o}{H}\right)^{\frac{3}{2}} = C_o(1 - p)^{\frac{3}{2}}$$

where $p = h_e/H$, ratio of entrance loss to total head; and, in which C_o is coef. of discharge under head H_o and:

$$C_o = \sqrt{2g}k(1 + k)\log_e \frac{1}{k}\frac{(1 - n)^{\frac{3}{2}}}{(1 - nk^2)^{\frac{3}{2}}}$$

—*H. E. Babbitt.*

Relation of Reynolds' Number R to Manning's *n*. ROBERT E. KENNEDY. Civ. Eng. **11:** 111 (Feb. '41). Frequently of interest to those working with pipe friction factors involving Reynolds' no., **R**, to find its equivalent in more familiar Manning's n. For this purpose, 3 factors: f, in $H_f = \frac{fLV^2}{D2g}$; n, in $V = \frac{1.486R^{2/3}s^{1/2}}{n}$; and $R = \frac{VD}{\nu}$; can be directly related in single equation which lends itself readily to construction of simple alinement chart. Final expression is: $\mathbf{R} = \frac{5.16n^6 10^{11}}{f^3}$. Nomenclature:

- **R** = Reynolds' no., non-dimensional
- V = mean velocity through cross-section, in fps.
- D = diam., in ft.
- R = hydraulic radius, in ft.
- ν = kinematic viscosity, in ft.^{2} per sec.
- f = friction factor in Darcy formula, in fps. (also known as λ)
- H_f = total head lost in energy grade, in ft.
- L = length of section, in ft.
- s = H_f/L
- g = acceleration due to gravity.

Discussion. Ibid. **11:** 173 (Mar. '41). A. A. KALINSKE. No natural relation between Reynolds' no. and n, since Manning formula is rough conduit formula and is applicable only when friction factor, f, is constant and does not vary with **R**. HUNTER ROUSE: Paper would seem to show close interdependence of 2 parameters, while in reality no such connection exists. *Ibid.* **11:** 359 (June '41). RALPH W. POWELL; Kennedy's equation may be written as: $f = \frac{185n^2}{D^{1/3}}$. At high velocities Manning's formula quite satisfactory; at one value of V (for each viscosity) it gives correct smooth pipe value; and for all lower velocities it gives too low values of f. Blind following of Manning's formula in open-channel flow may lead to difficulties.—*H. E. Babbitt.*

Simplified Flood Routing. OTTO H. MEYER. Civ. Eng. **11:** 306 (May '41). In investigation of rivers for flood control, or in similar hydraulic studies, flood routing likely to play important part. Existing methods for routing floods in rivers depend on flow-storage curves. In long reaches of shallow rivers, on other hand, time becomes important factor. Introduction of "time of travel" actually can reduce routing procedure to ultimate in simplicity, through application of what is here designated lag method. Essence of lag method that

storage at particular time governs outflow at some subsequent time. Routing by this method may be done with min. of labor by use of adding machine. Lag can best be determined in connection with construction of storage curve from historical flood. Known outflows subtracted from known inflows, and differences, which are increments of storage, accumulated algebraically. Time interval found between max. storage and max. outflow should be lag. When storage determined from maps or cross-sections, lag may be found by estimating time of travel through reach. Lag ½ of time of travel, which will vary with stage. In addition to saving time and labor, routing method has advantage that inflows used may be mean daily flows, which is form in which most of available data exist. Should be noted that applicability of method restricted to cases where lag not much less than ½ of smallest practicable time unit into which inflow hydrograph may be divided for routing.—*H. E. Babbitt.*

DAMS

Design of Hiwassee Dam—Basic Considerations. CECIL E. PEARCE. Civ. Eng. **10:** 340, 433 (June, July '40). Hiwassee Dam, now under construction, is in westernmost corner of N. C., and forms a part of TVA's program. Dam is straight, gravity structure, 307.5′ high, and 1,285′ long. Principal design data used in analyzing stresses in dam were: water, 62.5 lb. per cu.ft.; concrete, 154 lb. per cu.ft.; uplift, varying from 100% of hydrostatic head at upstream face to 50% at line of drains and to zero at downstream face, all acting over 66⅔% of area. Max. and min. principal stresses were 344.1 and 0.7 lb. per sq.in. respectively. Max. sliding factor was 0.638. Foundations were treated by two general methods: curtain grouting, or a line of grout holes near upstream face of dam; and blanket grouting, or general grouting over the entire remaining area of the foundation. No cut-off trench was used. Max. floods to be expected were based on formula: $R = \frac{5{,}000}{\sqrt{A}}$ in which R is rate of runoff in cu.ft. per sec. per sq.mi., and A is drainage area in square miles. Formula used for spillway design was $Q = \frac{3.80LH^{1.62}}{D^{0.12}}$ in which L is length of crest, H, actual head, and D, design head on crest. There are 4 sluice outlets with an inside diam. of 102″. A fixed nozzle is provided at downstream end of outlet, tapering in order to make downstream end the critical section at all flows. Gates of dam were closed on Feb. 8, '40 and water was impounded for flood control and low-water release. Relief from uplift is provided for by inspection galleries placed as near foundation as practicable. Where galleries cross contraction joints, corners were chamfered to prevent spalling. Keys were placed approx. on lower ⅓ of area of each contraction joint, and each contraction joint was provided with 20-gage, stainless steel, vertical water stop. Round formed drains placed on contraction joint to intercept any leakage that may get past system of water seals. On each of 4 regulating conduits, 1 ring-seal gate is intended to be operated either wide open or closed. Unique feature of emergency gate design is shape of bottom steel girder which is perforated. Perforation and lifting of beam, slightly above bottom of gate, cut hydraulic load about ½ and reduced required hoist capac. about 80 tons. Gantry crane provided at roadway level used for lowering or raising emergency gate in front of regulating conduit; for operating spillway gates; for lifting penstock intake gates; or for hoisting heavy equipment. At top of dam no. of details of utmost importance for appearance, usability, and general satisfaction. Roadway is 19′ wide, sidewalks, 4′ wide, curbs, 9″ high, and parapet designed for visibility. Believed that following precautions and methods should be employed on construction of all high masonry dams: (1) low-heat cement; (2) low cement content; (3) slow pouring schedule with long intervals between pours; (4) temp. control in mixing water; (5) several low lifts of pour over rock

foundations or old concrete; (6) careful excavation of all irregularities in foundation; (7) cooling of adjacent faces; and (8) avoidance of high exposed contraction joint faces of concrete. Power plant is at downstream toe of dam. Now contains one 80,000 hp. turbine with provision for future installation of duplicate unit. Elimination of power house bldg. will effect saving of $142,000 when second unit is installed. Deck of power plant is watertight since it forms roof of rooms below. Hydraulic installation includes 18′ diam. riveted-steel penstock, Francis-type turbine, elbow-type draft tube, and 3 draft-tube bulkhead gates for 3 sections of each draft tube. Switchyard is adjacent to powerhouse, on 4 benches cut into hillside.—*H. E. Babbitt.*

Time Required to Saturate an Earth Dam. K. P. KARPOFF. Civ. Eng. **11:** 238 (Apr. '41). In design of earth dams, time required to saturate embankment too often given only slight consideration. Time can be checked in field by recording time required for saturation to advance to successive hydrostatic indicators installed in cross-section of embankment. Equation, $t = \frac{L^2}{2\ kh' \cos\ \phi}$ (in which: t = time required to saturate unit section of dam; L = horizontal thickness of dam on plane h' below water surface; k = velocity of water through unit-area of soil in unit-time under unit-potential gradient; and ϕ = angle of downstream slope) limited to material in surface-dry condition. In computing time required to reach state of saturation, residual moisture (left in the dam after construction) must be taken into consideration. General formula then $t = \frac{L^2}{2\ kh' \cos\ \phi}\ V$, and specific formula, $t = \frac{[S + (H_d - a_o)m]^2}{2\ k\ (H_w - a_o \cos\ \phi}\ V$, in which V = correction factor determined by subtracting % by vol. of water remaining after construction from total % voids, as determined from consolidated dry density and absolute dry density; b = top width of dam; H_d = height of dam; $a_o = H_w - h'$; H_w = depth of water on upstream face of dam; m = slope of upstream face of dam; $S = b + (H_d - a_o)m_1$; and m_1 = slope of earth on downstream face of dam.—*H. E. Babbitt.*

Cavitations in Outlet Conduits of High Dams. HAROLD A. THOMAS AND EMIL P. SCHULEEN. Proc. A.S.C.E. **66:** 1623 (Nov. '40) (*see* Jour. A.W.W.A. **33:** 825 ('41)). *Discussion. Ibid.* **67:** 483 (Mar. '41). JEROME FEE: Authors' first equation based on assumption that "slug of water" travels with constant kinetic energy. If kinetic energy constant, momentum must change; but this means some external force, of which authors have taken no account, is acting. Entire argument must, therefore, be regarded as unsound. Authors develop numerical ratio between pressure of impact on water, and that on "rigid" surface. Writer feels certain that analysis is unsound. Conclusion that "velocity of particles at contact surface is ½ initial velocity of slug of water" not merely incorrect as to magnitude of this velocity. Based on wholly unreal idea. There are no "particles at contact surface" that can be distinguished in this manner from other particles, and whose velocity is susceptible of measurement or analysis—*H. E. Babbitt.*

Laboratory Experiments on Bellmouth Spillways. A. M. BINNIE AND R. K. WRIGHT. Surveyor (Br.) **99:** 203 (Mar. 21, '41). Provision of rubble or earthen dam with vertical bellmouth pipe for flood water attractive in unstable regions where rigid dam might be damaged seriously by earth tremors. In '37 W. J. E. Binnie described 7 bellmouth overflows at Burnhope, Hong Kong, and model expts. on which designs based. In '38 one of authors described investigation on lab. scale and demonstrated that above certain critical head, depending upon forms of tailpiece and inlet, pipe virtually refused to pass more water. Present paper gives an account of further work carried out at Eng. Lab., Oxford. Object of tests first described to determine relation between head, H, of water, above crest of bellmouth, discharge, Q, of water, and discharge of air drawn down with water. Authors present

analysis pointing to conclusion that complete head-discharge diagram for bellmouth and tailpiece can be predicted with some confidence, so long as vortices absent. Authors summarize results of 2 expts. as follows: (1) Above sharply marked critical head, bellmouth and pipe ran full and water flow remained almost constant at critical value. Below critical head, bellmouth acted as weir and water flow not reduced by entrainment of air. (2) At heads above critical, no permanent vortices formed. (3) All critical heads and water flows for various tailpieces attached to either bellmouth lay on head-discharge curve obtained with tailpiece that caused greatest flow. (4) Improved and practicable form of bellmouth (compared with two tested) could be designed. (5) When small tangential velocity imparted to water entering bellmouth, B, coefs. of discharge practically unaltered, but critical flow and head reduced considerably. At heads above critical, permanent vortex formed.—*H. E. Babbitt.*

Tilt of Dams Measured With Optical Device. ARTHUR W. ARLT. Civ. Eng. **11:** 273 (May '41). Because injection of grout produces elastic distortions and even permanent displacements in abutments or concrete masses, measurements of minute movements of these bodies provide one means of controlling and observing effects of grouting as that operation proceeds. Tiltmeter an optical instrument composed essentially of tripod frame, telescope with filar eyepiece, mercury pool with reflecting prism, and light source. Will indicate rotational movements in order of one second of arc in vertical plane through axis of telescope. Portable tiltmeters generally set up on foundation areas or in galleries of dams close to holes being grouted. Readings and notations of any tilting made periodically during grouting operations and assembled with other grouting data.—*H. E. Babbitt.*

Asphalt in Reservoir Construction. ANON. Wtr. & Wtr. Eng. (Br.) **42:** 352 (Oct. '40). In case of underground portions of reservoirs, necessary to incorporate, in design, adequate and efficient system of drainage, both under concrete floor and behind walls, to prevent accumulation of sub-soil water outside structure. Contraction joints should be placed at intervals not exceeding 50′. In construction of joints, common practice to make use of bitumen compounds or asphalt mixed with larger proportion of bitumen, either alone, or in conjunction with strip of copper or steel, crimped at center. Best results obtained by application of 3 coats of asphalt both to vertical sides of structure and to floors, vertical asphalt being $\frac{3}{4}$″ thick, and horizontal $1\frac{1}{4}$″ thick, all fillets to be in 2 coats. In case of unlined reservoirs, provided walls and floor are otherwise water tight, small cracks may be repaired by cutting out chase of sufficient size to cover crack, treating surface with mastic asphalt.—*H. E. Babbitt.*

Guide for Preparation of Journal Manuscripts

With a List of Standard Abbreviations

INFORMATION concerning the preparation of manuscripts for the JOURNAL, together with a list of abbreviations to be used, is presented here as a guide to authors and readers. Reprints of this material are available at no charge from A.W.W.A. headquarters.

These specifications, though by no means a compete manual of style, are to be considered the standard for preparation of papers to be published in the JOURNAL. Additional information regarding the points covered can be obtained from many books dealing specifically with the subject; a number of these are cited in the sample reference list below (2, 3, 4, 5).

Preparation of Manuscripts

Manuscripts should be typed on substantial white paper (capable of taking ink), 8½ by 11 in. in size. Typing should be double spaced, with margins 1 in. or more wide. The *original* copy of the manuscript should always be made available to the Association for the printer's use; carbons may be sent also, but the *original should always be sent.* Long words at the ends of lines should not be split to the next line. The hyphenation made necessary by splitting the words not only makes typesetting less accurate but makes reading of the paper before an audience more difficult.

All papers printed in the JOURNAL require certain data for a footnote which appears at the bottom of the first JOURNAL page. This information should be shown in paragraph form on a separate sheet and should include: date of presentation, name of section and location of section meeting before which it was presented, author's name as it should appear on the paper, author's title or position, author's business affiliation, and author's address.

It may be noted here that to make the original copy available to the Association, authors should always give it to the Section Secretary, who will transmit it to A.W.W.A. headquarters. All papers given at section meetings are primarily the property of the Association as far as publication is concerned.

Use of Subheads in Manuscripts

It will help the editor and enhance the ultimate presentation in printed form if the author will include in his manuscript the subheads which correspond to the divisions and subdivisions of his outline. The major division heads should be centered on the page, above the material to which they refer. Lesser subheads may be shown by underlining them and typing them flush to the left margin on a separate line. Some of these subheads may eventually be eliminated by the editor when the paper is fitted to the JOURNAL page, but the author's suggested headings are most helpful.

Illustrations and Tables

All illustrations, including charts, graphs, diagrams, photographs, etc., which the author thinks might enhance the presentation of his material, should be submitted with his manuscript. Photographs should be good clear glossy prints; charts, diagrams, graphs, etc., should be on tracing cloth whenever possible. (All illustrative material is always returned to the author.)

Illustrations, regardless of what type they are, should be labeled consecutively (Fig. 1, Fig. 2, etc.) in the order to which they are referred in the text of the paper. Each figure should be either a separate sheet in itself or mounted on a separate sheet. The correct titles for the figures should also be listed, by figure number, on a separate sheet.

Tables should be numbered consecutively in the order in which reference is made to them in the text of the paper. Each table should be shown on a separate sheet and should never be included in the body of the text material. The use of proper abbreviations consistently in making up tables will make the presentation clearer and less space-consuming.

References

References should always be cited by number, i.e., (1), (2), (3), etc., within the body of the text. Complete reference data should then be typed on a separate sheet. The complete references should never be written into the text or included as footnotes. Reference data should include: for periodicals (1, 5, 6, 7)—author's name complete, title of article, name of publication, volume number, issue number (if paged within the issue (7)), page number, and year of publication; for books (2, 3, 4)—author's name complete, title of book, publisher's name and address, edition, and year of publication. The following is a sample reference list:

References

1. Guide for Preparation of Journal Manuscripts With a List of Standard Abbreviations, Jour. A.W.W.A., 34:000 (1942).

2. Howell, A. C. A Handbook of English in Engineering Usage. John Wiley, New York (2nd ed., 1940).

3. Benbow, John. Manuscript and Proof. Oxford Univ. Press, New York (2nd ed., 1938).

4. A Manual of Style. Univ. of Chicago Press, Chicago (10th ed., 1937).

5. Norton, John F. Critical Appraisal of Experimental Work. Jour. A.W.W.A., 33:1497 (1941).

6. Lamar, William L. and Seegmiller, Charles G. Determination of Small Quantities of Fluoride in Water. Ind. Eng. Chem.--Anal. Ed., 13:901 (1941).

7. Thompson, Horace. Oklahoma City Water Supply Being Improved and Enlarged. Am. City, 56:12:60 (1941).

When the manuscript is put in final order, the author will find it much easier to prepare a proper reference list if careful reference notes have been kept throughout the progress of the study. The author cannot give *too complete* data on each reference, but he should avoid giving *too many* references.

Style

Aside from the technical aspects of preparation of manuscripts, the matter of style is an important factor in the final product. Any one of the three books (references 2, 3 and 4 in the sample list above) will serve as an adequate guide to style in writing. What is most important is consistency—*consistency* in outline, in spelling, in hyphenation, and in punctuation. An examination of recent copies of the JOURNAL will indicate the general points of style preferred.

Journal Abbreviations

In the first, and major, list of abbreviations, the terms *in italics* are the *only* ones to be abbreviated in the *text portion* of the JOURNAL. The rule is to use the abbreviations for units of measurement *only* when they accompany numerals. In general, other abbreviations used in the text are those for governmental units, agencies, other organizations and for addresses, titles, etc. A most important rule is: *When in doubt, spell it out.* The words and terms not italicized in this list are to be abbreviated *only* in the JOURNAL Abstracts section, where abbreviations are used whenever possible. The list is not to be considered complete, but it does include the abbreviations in general use in the water works field; others may be employed when applicable, in individual papers or abstracts.

The letter or letters chosen for each abbreviation or symbol to be used in the text portion are generally those contained in "American Standard Abbreviations for Scientific and Engineering Terms (ASA Z10.1—1941)" as approved by the American Standards Association in March 1941. JOURNAL abbreviations differ from those of the ASA Standard in that most JOURNAL abbreviations or symbols are followed by a period (to show clearly that they are abbreviations); thus the majority of abbreviations currently used are those used previously.

A number of the abbreviations to be used in the Abstracts section are those employed in *Chemical Abstracts*; others, of specifically water works terms, have been devised after the same style.

In the second list are shown the proper abbreviations of the names of the states and provinces. These names should be abbreviated in all cases where they follow the name of a municipality. *When they stand alone they should be spelled out.*

Abbreviations of Technical Words and Terms

(Only abbreviations in italics used in Text portion; all abbreviations used in Abstracts)

absolute	abs.
account (s)	acct. (s)
accounted	acctd.
accounting	acctg.
acre-foot	acre-ft.
addition (s)	addn. (s)
additional	addnl.
administration, administrative	admin.
alcohol (ic)	alc.
alkaline	alk.
alkalinity	alky.
alternating-current (adj.)	a-c.
American	Am.
amount (s)	amt. (s)
amounted	amtd.
amounting	amtg.
ampere (s)	amp.
ampere-hour (s)	amp-hr.
analysis, analytical	anal.
analyses	anals.
Ångstrom unit	Å
anhydrous	anhyd.
aqueous	aq.
atmosphere (s)	atm.
atomic weight	at.wt.
average (s)	avg. (s)
averaged	avgd.
averaging	avgg.
avoirdupois	avdp.
bacterial, bacteriological	bact.
barrel (s)	bbl.
biochemical oxygen demand	B.O.D.
biological	biol.
board feet (feet board measure)	fbm.
boiling point	bp.
brake horsepower	bhp.
brilliant green bile broth	B.G.B.
British thermal unit	Btu.
building (s)	bldg. (s)
bushel (s)	bu.
calculate (s)	calc. (s)
calculated	calcd.
calculating	calcg.
calculation	calcn.
calorie (s)	cal.
capacity (ies)	capac. (s)
cast-iron (adj.)	c-i.
center to center	c. to c.
centigram (s)	cg.
centiliter (s)	cl.
centimeter (s)	cm.
chemical (s)	chem. (s)
chemically pure	cp.
coefficient (s)	coef. (s)
composition	compn.
compound (s)	compd. (s)
concentrate (s)	conc. (s)
concentrated	concd.
concentrating	concg.
concentration	concn.
conductivity	cond.
constant	const.
construction	constr.
containing	contg.
contaminate (s)	contam. (s)
contaminated	contamd.
contaminating	contamg.
contamination	contamn.
cosecant	csc
cosine	cos
cotangent	cot
counter electromotive force	cemf.
crystalline	cryst.
cubic	cu.
cubic centimeter (s)	cc.
cubic foot	cu.ft.
cubic feet per minute	cfm.
cubic feet per second	cfs.
cubic inch	cu.in.
cubic meter (s)	cu.m.
cubic micron (s)	cu.μ
cubic millimeter (s)	cu.mm.
cubic yard (s)	cu.yd.
decomposition	decompn.
degree (s)	deg.
degree (s)	°
degree Centigrade	°C.
degree Fahrenheit	°F.
depreciation	depn.
determination	detn.
determine (s)	det. (s)
determined	detd.
determining	detg.
diameter (s)	diam. (s)
direct-current (adj.)	d-c.
dilute (s)	dil. (s)
diluted	dild.
diluting	dilg.
dilution	diln.
dissolved oxygen	D.O.
distribution	distr.
distill (s)	dist. (s)
distillation	distn.
distilled	distd.

distilling	distg.
dozen	doz.
dram (s)	dr.
efficiency	eff.
electric (al)	elec.
electromotive force	emf.
elevation	el.
eosin methylene blue	E.M.B.
Equation	Eq.
equipment	equip.
estimate (s)	est. (s)
estimated	estd.
estimating	estg.
evaporate (s)	evap. (s)
evaporated	evapd.
evaporating	evapg.
evaporation	evapn.
examine (s)	exam. (s)
examined	examd.
examining	examg.
examination	examn.
experiment (s)	expt. (s)
experimental	exptl.
experimented	exptd.
experimenting	exptg.
external	ext.
feet	ft.
feet	′
feet board measure (board feet)	fbm.
feet per minute	fpm.
feet per second	fps.
Figure	Fig.
foot	ft.
foot	′
foot-pound (s)	ft.-lb.
free on board	fob.
freezing point	fp.
gallon (s)	gal.
gallons per day	gpd.
gallons per minute	gpm.
gallons per second	gps.
government	govt.
governmental	govtl.
grain	(spell out)
grains per gallon	gpg.
gram (s)	g.
hectare (s)	ha.
high-pressure (adj.)	h-p.
hogshead (s)	hhd.
horsepower	hp.
horsepower-hour (s)	hp-hr.
hour (s)	hr.
hundredweight	cwt.
inch (es)	in.
inch (es)	″
inch-pound (s)	in-lb.
inches per second	ips.
indicated horsepower	ihp.
indicated horsepower-hour (s)	ihp-hr.
inorganic	inorg.
inside diameter	id.
intermediate-pressure (adj.)	i-p.
internal	int.
kilocycles per second	kc.
kilogram (s)	kg.
kilogram-calorie (s)	kg-cal.
kilogram-meter (s)	kg-m.
kilograms per second	kgps.
kiloliter (s)	kl.
kilometer (s)	km.
kilometers per second	kmps.
kilovolt (s)	kv.
kilovolt-ampere (s)	kva.
kilowatt (s)	kw.
kilowatthour (s)	kwhr.
laboratory (ies)	lab. (s)
lactose broth	L.B.
latitude	lat.
linear foot	lin.ft.
liquid	liq.
liter (s)	l.
logarithm (common)	log
logarithm (natural)	$\log_e$
longitude	long.
low-pressure (adj.)	l-p.
maintain (s), maintenance	maint. (s)
maintained	maintd.
maintaining	maintg.
mathematics (al)	math.
maximum	max.
mean effective pressure	mep.
melting point	mp.
meter (s)	m.
meter-kilogram (s)	m-kg.
microampere (s)	μa.
microinch (es)	μin.
micromicron (s)	μμ
micron (s)	μ
microvolt (s)	μv.
microwatt (s)	μw.
mile (s)	mi.
miles per hour	mph.
miles per hour per second	mphps.
milliampere (s)	ma.
milligram (s)	mg.
milliliter (s)	ml.
millimeter (s)	mm.
millimicron (s)	mμ
million gallons	mil.gal.
million gallons per day	mgd.
millivolt (s)	mv.
minimum	min.

minute (*s*)	min.
molecular (*concentration*)	M
molecular weight	mol.wt.
month (s)	mo.
most probable number	M.P.N.
normal (*concentration*)	N
Number (*s*)	No. (s)
organic	org.
ounce (*s*)	oz.
ounce-foot	oz-ft.
ounce-inch (*es*)	oz-in.
outside diameter	od.
parts per million	ppm.
peck (*s*)	pk.
pennyweight	dwt.
per	/
per cent	%
physical	phys.
pollution	poln.
population (s)	pop. (s)
pounds per square foot	psf.
pounds per square inch	psi.
pounds per square inch absolute	psia.
powder (ed)	powd.
precipitate (s)	ppt. (s)
precipitated	pptd.
precipitating	pptg.
precipitation	pptn.
preparation	prepn.
prepare (s)	prep. (s)
prepared	prepd.
preparing	prepg.
purification	purif.
quality (ies), qualitative	qual. (s)
quantity (ies), quantitative	quant. (s)
quart (*s*)	qt.
revolutions per minute	rpm.
revolutions per second	rps.
root mean square	rms.
saturated	satd.
saturating	satg.
saturation	satn.
second (*s*)	sec.
significant (ance)	signif.
sine	sin
solution (s)	soln. (s)
specific gravity	sp.gr.
specific heat	sp.ht.
square	sq.
square centimeter (*s*)	sq.cm.
square foot	sq.ft.
square inch (*es*)	sq.in.
square kilometer (*s*)	sq.km.
square meter (*s*)	sq.m.
square micron (*s*)	sq.μ
square millimeter (*s*)	sq.mm.
standard (s)	std. (s)
tangent	tan
temperature (s)	temp. (s)
tensile strength	ts.
United States Pharmacopoeia	U.S.P.
volt (*s*)	v.
volt-ampere (*s*)	va.
volume (s)	vol. (s)
watt (*s*)	w.
watthour (*s*)	whr.
week (*s*)	wk.
weight	wt.
yard (*s*)	yd.
year (*s*)	yr.

Abbreviations of States and Provinces

Ala.	Iowa	N.B.	R.I.
Alta.	Kan.	N.H.	Sask.
Ariz.	Ky.	N.J.	S.C.
Ark.	La.	N.M.	S.D.
B.C.	Me.	N.Y.	Tenn.
Calif.	Man.	N.C.	Tex.
Colo.	Md.	N.D.	Utah
Conn.	Mass.	N.S.	Vt.
Del.	Mich.	Ohio	Va.
D.C.	Minn.	Okla.	Wash.
Fla.	Miss.	Ont.	W.Va.
Ga.	Mo.	Ore.	Wis.
Idaho	Mont.	Pa.	Wyo.
Ill.	Neb.	P.E.I.	
Ind.	Nev.	Que.	

TITLE 32—NATIONAL DEFENSE

Chapter IX—Office of Production Management

Subchapter B—Priorities Division

Part 978—Utilities, Maintenance, Repair and Supplies

AMENDMENT NO. 1 TO PREFERENCE RATING ORDER NO. P-46

Issued: September 26, 1941

Because it has been found that a number of public utilities have fiscal years other than the calendar year, the order has been amended to authorize a producer to use the closing day of its fiscal year, which ended during 1940, as the basis for determining a practical working minimum inventory.

(a) Part 978.1, paragraph (f) (2), is hereby amended to read as follows:

(f) (2) No Producer shall, at any time, accept deliveries (whether or not rated pursuant to this Order) of any item of Material to be used as Operating Supplies or for Maintenance or Repair or any other purpose until the Producer's Inventory and stores of items of Material of the same class have been reduced to a practical working minimum, unless such delivery shall be specifically authorized in advance by the Office of Production Management on the Producer's application therefor. Such practical minimum shall in no case exceed the aggregate dollar volume of items of Material of the same class in inventory and stores on December 31, 1940, or, at the Producer's option, at the close of the Producer's fiscal year ending during the calendar year 1940.

(b) This Order shall take effect immediately.

(signed)

DONALD M. NELSON
Director of Priorities

[The Office of Production Management, on November 25, 1941, defined what is meant by "minor improvements" and "minor capital additions" for utility systems covered by Preference Rating Order P-46.

Under this order a preference rating of A-10 is assigned to supplies needed for repair, maintenance and operation, and for "minor improvements" and "minor capital additions." This led to uncertainty among

utilities as to what constituted "minor improvements" or "minor capital additions."

Amendment No. 2 to P-46, puts an end to the uncertainty by providing that a minor improvement or minor capital addition is an expenditure for material not exceeding $1500 in the case of underground connections, or $500 for other capital additions. A job may not be split up in order to come within those limits. Another clause in the amendment liberalizes the acquisition or withdrawal of supplies needed to repair property or equipment damaged by fire, flood, or other climatic occurrences. Other provisions in the amendment clarify sections in the original order dealing with inventories and the replacement of condemned meters.

Amendment No. 2 follows.]

AMENDMENT NO. 2 TO PREFERENCE RATING ORDER NO. P-46

Issued: November 25, 1941

(a) Section 978.1, as heretofore amended, is hereby amended as follows:

(1) Paragraph (a) (6) (ii) is amended to read as follows:

(ii) additions to, or expansion of, such property or equipment, other than the connection of new consumers, and minor improvements needed for relief from serious overload and other minor capital additions; *Provided*, that such connection or new consumers, minor improvements and other minor capital additions shall not include any work order or job in which the cost of Material shall exceed $1500 in the case of underground connections, and $500 in the case of other capital additions, and provided further that no single job shall be subdivided into parts in order to come below these limits;

(2) Paragraph (f) is amended to read as follows:

(f) *Restrictions on Deliveries, Withdrawals and Inventory.*

(1) No Producer shall, during any Calendar Quarterly Period, accept deliveries (whether or not rated pursuant to this Order) of any items of Material to be used as Operating Supplies or for Maintenance or Repair or any other purpose the aggregate dollar volume of which shall exceed 25% of the aggregate dollar volume of the withdrawals of items of Material of the same class from stores or inventory during the calendar year 1940 unless such deliveries shall be specifically authorized in advance by the Office of Production Management on the Producer's application therefor.

(2) No Producer shall, at any time, accept deliveries (whether or not rated pursuant to this Order) of any item of Material to be used as Operating Supplies or for Maintenance or Repair or any other purpose until the Producer's inventory and stores of items of Material of the same class have been reduced to a practical working minimum, unless such delivery shall be specifically authorized in

advance by the Office of Production Management on the Producer's application therefor. Such practical minimum shall in no case exceed the aggregate dollar volume of items of Material of the same class in inventory and stores on December 31, 1940, or, at the Producer's option, on the most recent date during the calendar year 1940 on which the Producer's inventory was taken.

(3) No Producer shall, during any Calendar Quarterly Period, make withdrawals from stores or inventory of any items of Materials to be used as Operating Supplies or for Maintenance or Repair or for any other purpose the aggregate dollar volume of which shall exceed the aggregate dollar volume of the withdrawals of such items of Material of the same class during the corresponding quarter of 1940, or, at the Producer's option, 25% of the aggregate dollar volume of the withdrawals of such items of Material of the same class during the calendar year 1940 unless such withdrawals shall be specifically authorized in advance by the Office of Production Management on the Producer's application therefor.

(4) Notwithstanding the provisions contained in paragraphs (f) (1), (2) and (3), a Producer may:

(i) in any Calendar Quarterly Period increase the aggregate dollar volume of deliveries accepted of Material for Operation, Maintenance and Repair of generation, production and pumping facilities, and withdrawals of Material for such use, over the aggregate dollar volume of deliveries or withdrawals of Material for such use during the corresponding calendar quarter of 1940 proportionately to the increase in system output in the preceding Calendar Quarterly Period over the system output in the Calendar Quarter of 1940 corresponding to such preceding Calendar Quarterly Period; and

(ii) in any Calendar Quarterly Period accept deliveries which will increase the aggregate dollar volume of inventory of Material for the Operation, Maintenance and Repair of generation, production and pumping facilities over the aggregate dollar volume of inventory of Material for such use on December 31, 1940, or, at the Producer's option, on the most recent date on which the Producer's inventory was taken during the calendar year 1940, proportionately to the increase in system output during the preceding Calendar Quarterly Period over the system output in the Calendar Quarter of 1940 corresponding to such preceding Calendar Quarterly Period; and

(iii) in any Calendar Quarterly Period accept deliveries or make withdrawals from stores or inventory of consumers' meters and house-regulators in an amount not in excess of 25% of the number

of such meters or house-regulators condemned and destroyed by the Producer in 1940, (or, at the Producer's option, not in excess of the number of such meters and house-regulators condemned and destroyed in the corresponding quarter of 1940) plus the number of meters and house-regulators necessary to serve the net increase in customers occurring in the current quarter. For the purposes of this sub-paragraph (iii) withdrawals of meters and house-regulators shall not include meters or house-regulators put in service to replace meters and house-regulators removed from service; and

(iv) in order to provide for unavoidable and emergency situations, accept in any Calendar Quarterly Period deliveries of Material in excess of the amounts specified in paragraphs (f) (1), (2) and (4) (i) and (ii), or make withdrawals from stores or inventory of Material in excess of the amounts specified in paragraphs (f) (3) and (4) (i), such excess, however, not to exceed 2% of the aggregate dollar volume of Material of the same class in inventory on December 31, 1940, or, at the Producer's option, on the most recent date during the Calendar year 1940 on which the Producer's inventory was taken; and

(v) in any Calendar Quarterly Period accept deliveries or make withdrawals of Material to the extent necessary for the Maintenance or Repair of the Producer's property or equipment which is damaged by fire, flood, or other climatic conditions, provided that, if the restrictions in paragraphs (f) (1), (2) or (3), as modified by the provisions of paragraphs (f) (4) (i), (ii), and (iv), are exceeded because of such deliveries or withdrawals, a full report of such deliveries or withdrawals together with the reasons therefor shall be made immediately to the Office of Production Management, and provided that the Producer shall, to the extent that the aggregate dollar volume of such deliveries or withdrawals exceeds the aggregate dollar volume of deliveries or withdrawals authorized in paragraphs (f) (1) and (3), as modified by the provisions of paragraphs (f) (4) (i), (ii), and (iv), make adjustments for such excess in the two succeeding Calendar Quarterly Periods unless exemption from this proviso shall be specifically authorized by the Office of Production Management.

(5) The provisions of this paragraph (f) shall not apply to fuel, water purification chemicals, wooden poles or wooden crossarms.

(b) This Order shall take effect immediately.

(Signed)
J. S. KNOWLSON
Acting Director of Priorities

AMENDMENT NO. 3 TO PREFERENCE RATING ORDER NO. P-46

WHEREAS, maintenance, repair, operation and expansion of property and equipment of public utilities consumes large quantities of copper, zinc, iron, steel and aluminum; national defense requirements have created a shortage in these materials for defense, private account and for export; and the present supply of these materials will be insufficient for defense and essential civilian requirements unless the current rate of consumption of such materials for maintenance, repair, operation and expansion of public utility property and equipment is limited to the minimum quantities essential for such purposes;

NOW, THEREFORE, IT IS HEREBY ORDERED THAT:

(a) Section 978.1 as heretofore amended is hereby amended as follows:

1. Paragraph (a) (1) is amended to read as follows:

(1) "Producer" means any individual, partnership, association, corporation, governmental unit or other form of organization engaged in one or more of the following services:

(i) supplying electric power directly or indirectly for general use by the public;

(ii) supplying gas, natural or manufactured, directly or indirectly for general use by the public;

(iii) supplying water directly or indirectly for general use by the public;

(iv) public sanitation services, but not including manufacturers of public sanitation products;

(v) supplying central steam heating directly or indirectly for general use by the public.

The term "Producer" includes any producer as herein defined, whether or not such producer has executed the acceptance attached hereto.

2. Paragraph (f) (3) is hereby amended to read as follows:

(3) (i) No Producer shall, during any Calendar Quarterly Period, make withdrawals from stores or inventory of any items of Materials to be used as Operating Supplies or for Maintenance or Repair or for any other purpose the aggregate dollar volume of which shall exceed the aggregate dollar volume of the withdrawals of such items of Material of the same class during the corresponding quarter of 1940, or, at the Producer's option, 25% of the aggregate dollar volume of the withdrawals of such items of Material of the same class during the calendar year 1940 unless such withdrawals shall be specifically authorized in advance by the Office of Production Management on the Producer's application therefor.

(ii) No Producer shall make withdrawals from stores or inventory of Material to be used for additions to or expansion of property or equipment without securing approval in advance from the Office of Production Management, unless

(*a*) the project or job is under construction and 40% of the total dollar value thereof is installed on December 5, 1941; or

(*b*) the cost of material for the work order, job or project is less than $1500 in the case of underground connections and $500 in the case of other additions to or expansion of property or equipment; provided, however, that no single work order, job or project shall be subdivided into parts in order to come below these limits, and provided further that in no event shall lines be extended more than 1000 feet from existing facilities.

3. Paragraph (g) is amended to read as follows:

(g) *Audits and Reports.*

(1) Each Producer and each Supplier who applies the preference rating hereby assigned, and each person who accepts a purchase order or contract for Material to which the preference rating is applied, shall submit from time to time to an audit and inspection by duly authorized representatives of the Office of Production Management.

(2) Each Producer and each such Supplier shall execute and file with the Office of Production Management such reports and questionnaires as said Office shall from time to time request. No such reports shall be filed until such time as the proper forms are prescribed by the Office of Production Management.

(3) Each Producer shall maintain a continuing inventory of Material included in stores accounts.

(b) This Order shall take effect immediately.

(P.D. Reg. 1, Aug. 27, 1941, 6 F.R. 4489; O.P.M. Reg. 3 Amended, Sept. 2, 1941, 6 F.R. 4865; E.O. 8629, Jan. 7, 1941, 6 F.R. 191; E.O. 8875; Aug. 28, 1941, 6 F.R. 4483; sec. 2(a) Public No. 671, 76th Congress, Third Session, as amended by Public No. 89, 77th Congress, First Session; sec. 9 Public No. 783, 76th Congress, Third Session.)

Issued this 11th day of December, 1941.

(signed)
DONALD M. NELSON
Director of Priorities

TITLE 32—NATIONAL DEFENSE

Chapter IX—Office of Production Management

Subchapter B—Priorities Division

Part 960—Chlorine

AMENDMENT NO. I TO GENERAL PREFERENCE ORDER NO. M-19—TO CONSERVE THE SUPPLY AND DIRECT THE DISTRIBUTION OF CHLORINE

(a) Section 960.1 (General Preference Order No. M-19) is hereby amended to read as follows:

WHEREAS, the national defense requirements have created a shortage of Chlorine, as hereinafter defined, for defense, for private account, and for export, and it is necessary, in the public interest and to promote the defense of the United States, to conserve the supply and direct the distribution thereof;

NOW, THEREFORE, IT IS HEREBY ORDERED THAT:

960.1 GENERAL PREFERENCE ORDER (a) *Definitions.* For the purposes of this Order:

(1) "Chlorine" means gaseous and liquid Chlorine.

(2) "Producer" means any person engaged in the production of Chlorine and includes any person who has Chlorine produced for him pursuant to toll agreement.

(3) "Distributor" means any person who purchases Chlorine for resale.

(b) *Applicability of Priorities Regulation No. 1.* Control of the supply and direction of the distribution of Chlorine is hereby taken by the Director of Priorities, and all future transactions of any kind in Chlorine are regulated and governed by the provisions and definitions contained in Regulation No. 1 of the Priorities Division of the Office of Production Management, issued on the 27th day of August, 1941, except as herein otherwise specifically provided.

(c) *Placing Orders.* Anything in Priorities Regulation No. 1 to the contrary, notwithstanding,

(1) No Producer shall, except as the Director of Priorities may otherwise direct, accept an order, whether it be that of a Distributor, another Producer, or consumer, for delivery of Chlorine unless such order has been placed with him by the 10th day of the month preceding the month in which delivery is sought, and unless such order is accompanied by Form PD-190 (in duplicate) properly executed by the person placing such an order. The Form PD-190 submitted by a Distributor must be accompanied by the original

and one copy of Form PD-190 submitted to him in accordance with the provisions of paragraph (c) (2) hereof in connection with orders accepted by him.

(2) No Distributor shall, except as the Director of Priorities may otherwise direct, accept an order for delivery of Chlorine unless such order has been placed with him by the 5th day of the month preceding the month in which delivery is sought and unless such order is accompanied by Form PD-190 (in triplicate) properly executed by the person placing such order.

(3) No producer or Distributor shall make, and no person shall accept, delivery of Chlorine unless and until Form PD-190 hereinabove referred to has been properly executed and timelily filed in accordance with the provisions of paragraphs (c) (1) and (2) hereof.

(d) *Withheld Deliveries.*

(1) No Producer shall make commitments for the sale or delivery of liquid Chlorine during the month of February, 1942, or any calendar month thereafter, with respect to an amount of liquid Chlorine equal to five percent (5%) of his estimated monthly production.

(2) No Producer shall deliver liquid Chlorine as to which commitments may not be made pursuant to paragraph (d) (1) hereof, except upon express instructions of the Director of Priorities. If by the 15th day of the month in which a Producer is required by the provisions of paragraph (d) (1) hereof to withhold deliveries of liquid Chlorine, the Director of Priorities has issued no instructions with respect to the disposition of such liquid Chlorine, Producers may make deliveries of such liquid Chlorine without regard to the restrictions contained in paragraph (c) hereof, but subject, however, to the provisions of Priorities Regulation No. 1.

(e) *Delivery Schedules.*

(1) Form PD-191 (in triplicate) properly executed, which shall contain, among other things, a schedule of deliveries which such Producer proposes to make in the succeeding month, the preference rating, if any, applicable to each delivery, the orders tendered to him for delivery during the succeeding month which he has not scheduled, his estimated production for the succeeding month and the amount of liquid Chlorine to be reserved for the succeeding month in accordance with the provisions of paragraph (e) hereof, shall on or before the 15th day of each calendar month be filed by each Producer with the Chemicals Branch of the Office of Production Management, Washington, D. C. Such Form PD-191 shall be accompanied by the duplicate copies of every Form PD-190

submitted to the Producer. After such Form PD-191 has been filed with the Chemicals Branch of the Office of Production Management, any changes of circumstances or matters occurring thereafter affecting the accuracy of the statements contained in such Form PD-191 shall be forthwith reported to the Chemicals Branch of the Office of Production Management.

(2) On and after February 1, 1942, except as provided in paragraph (d) (2) hereof and except as may be otherwise specifically authorized by the Director of Priorities, no deliveries of Chlorine shall be made by a Producer to any person unless and until the same shall have been authorized by the Director of Priorities. Such authorization by the Director of Priorities shall be based primarily upon insuring the satisfaction of all defense requirements and providing an adequate supply for essential civilian uses. Each Producer shall, upon being apprised of the deliveries which have been authorized by the Director of Priorities, forthwith notify his customers of the extent of such authorization as the same may affect them. Each Distributor shall, upon being apprised by the Producer of the extent to which deliveries to such Distributor have been authorized by the Director of Priorities, forthwith notify his customers of the extent of such authorization as the same may affect them. If, however, by the 25th day of the month preceding the month in which deliveries are to be made, no instructions have been issued by the Director of Priorities, Producers may make deliveries of Chlorine in accordance with, and only in accordance with, the schedules filed by them with the Chemicals Branch of the Office of Production Management.

(f) Assignment of Preference Ratings.

(1) Deliveries under all defense orders which have not been assigned a higher preference rating are hereby assigned a preference rating of A-10.

(2) Unless a higher preference rating has been specifically assigned by order of the Director of Priorities, and subject to Priorities Regulation No. 1, deliveries of Chlorine for the uses (or for the manufacture of products for such uses) set forth below are hereby assigned the preference rating set opposite each such use as follows:

Use	*Preference Rating*
(i) Potable water treatment Sewage treatment	A-2
(ii) Sanitation and sterilization in hospitals, clinics, sanitoria, diaper laundries, dairies and other food processing plants, public eating and drinking estab-	A-6

lishments, public and institutional swimming pools, surgical and medical supply manufacturing establishments.
Manufacture of products for medicinal, surgical, dental and veterinarian uses.

(iii) Food processing other than bleaching — A-9
Food preservation

(iv) Manufacture of vitamin products — A-10
Manufacture of insecticides and fungicides
Manufacture of catalyst materials
Industrial water treatment
Metals refining

(v) Processing of pulps, as follows: — B-2
(a) High alpha pulps (not less than 90% Alpha Cellulose content)
(b) Dissolving pulps
(c) Nitrating pulps
(d) Pulps used in the manufacture of photographic base papers
(e) Pulps in which Chlorine is a processing rather than a bleaching chemical.
Manufacture of petroleum product additives
Manufacture of industrial chemicals and related products.
Manufacture of industrial plastics and rubber-like products

(vi) Textile bleaching — B-5
Pulp and paper bleaching not elsewhere classified
Shellac bleaching
Laundry bleaching

(vii) Foodstuff bleaching — B-8
Wiping rag and waste bleaching
Cosmetics and toilet preparation

(g) *Acceptance of Certain Non-Defense Orders.* When a non-defense order for Chlorine for a use specified in paragraph (f) (2) hereof to which a preference rating has been assigned, either by specific certificate or otherwise, is offered to a Producer or a Distributor, it shall, subject to the same terms and conditions applicable to the acceptance of defense orders set forth in Priorities Regulation No. 1, be accepted for scheduling on Form PD-191; and deliveries thereunder shall be scheduled in accordance with the preference rating assigned thereto and the delivery dates specified therein, even though deferment of deliveries under non-defense orders

bearing a lower preference rating previously accepted is necessitated thereby, such deliveries thereunder scheduled to be subject, however, to revision by the Director of Priorities under the terms and conditions set forth in this Order. Deliveries shall then be made in accordance with the authorization of the Director of Priorities. Any person seeking to place a non-defense order to which a preference rating has been assigned must make application for acceptance of such order in the first instance to his regular Supplier (if a person has several regular Suppliers, the order should be divided among such Suppliers in accordance with each such person's normal method of placing orders).

(h) *Intra Company Transactions.* The prohibitions or restrictions contained in this Order with respect to acceptances of orders and deliveries in the absence of a contrary direction apply not only to acceptances of orders from and deliveries to other persons, including affiliates and subsidiaries, but also to acceptances of orders from and deliveries to one branch, division or section of a single enterprise by or from another branch, division or section of the same or any other enterprise owned or controlled by the same person.

(i) *Reports.* Reports required by Priorities Regulation No. 1 hereinabove referred to shall be made at such times and on such forms as shall be prescribed therefor by the Chemicals Branch of the Office of Production Management.

(j) *Notification of Customers.* Producers and Distributors shall, as soon as practicable, notify each other of their regular customers of the requirements of this Order, but the failure to give such notice shall not excuse any person from the obligation of complying with the terms of this Order.

(k) *Violations or False Statements.* Any person who violates this Order, or who wilfully falsifies any records which he is required to keep by the terms of this Order, or by the Director of Priorities, or otherwise wilfully furnishes false information to the Director of Priorities or to the Office of Production Management may be deprived of priorities assistance or may be prohibited by the Director of Priorities from obtaining further deliveries of materials subject to allocation. The Director of Priorities may also take any other action deemed appropriate, including the making of a recommendation for prosecution under Section 35(A) of the Criminal Code (18 U. S. C. 80).

(l) *Effective Date.* This Order shall take effect immediately and shall continue in effect until revoked by the Director of Priorities.

Issued this 20th day of December, 1941.

(signed)

DONALD M. NELSON
Director of Priorities